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APPENDIX NO. 2 TO THE ANNUAL REPORT OF THE
CHIEF OF THE BUREAU OF NAVIGATION, 1917

ANNUAL REPORT OF THE
NAVAL OBSERVATORY

FOR THE

FISCAL YEAR 1917

WASHINGTON
GOVERNMENT PRINTING OFFICE
1917

APPENDIX No. 2.

REPORT OF SUPERINTENDENT OF NAVAL OBSERVATORY.

NAVY DEPARTMENT,
UNITED STATES NAVAL OBSERVATORY,
Washington, D. C., July 1, 1917.

From: Superintendent, Naval Observatory.
To: Bureau of Navigation.
Subject: Report of the Superintendent, Naval Observatory, for the fiscal year ending June 30, 1917.

Capt. J. A. Hoogewerff, United States Navy, continued as superintendent to March 31, 1917, when he was relieved by the present superintendent, Rear Admiral T. B. Howard, United States Navy, retired.

The time signals were sent out twice daily during the year, at noon and 10 p. m., seventy-fifth meridian time, both by land lines and by radio, through the operating relay at Radio, Va. The improvements mentioned in the last annual report have been completed and put in operation. The accuracy of the radio time signals, which can be picked up anywhere in the north Atlantic, has made it possible to reduce to one the allowance of chronometers for vessels of the Navy operating along the Atlantic coast. The number of requests for exemption from the order for dismantling privately owned receiving sets, coming from watch manufacturers, jewelers, and scientific laboratories and observatories, proved how popular the custom of receiving time signals by radio has become.

The Naval Observatory has continued the policy of encouraging suggestions and developments of methods and instruments for navigation, particularly for submarines and aircraft.

The nautical instrument repair shop has continued to prove economical in time and expense as compared with the previous system of having this work done by contract. During the year ending June 30, 1917, there were 3,251 instruments repaired, an increase of more than 27 per cent over the number repaired in the preceding year. It has been found by trial that chronometers and torpedo-boat watches repaired in the shop receive trial numbers as low as those repaired by commercial firms. Also, a large number of instruments have been reconstructed from parts of instruments condemned by survey. There is now available an appropriation for increasing the size of the repair shop. This increase, when accomplished, will further improve the quality and diminish the cost of the work done.

Owing to the great increase in ships of the Navy and the lack of receipt of materials and nautical instruments from abroad and the shortage of skilled labor in this country, especially in the manufacture of instruments and chronometers, the question of supply of instruments for navigation, especially chronometers, is becoming a matter of very serious proportions. The increased demand for the gyro-compass and the instruments attached to it is taxing the capacity of the only factory in this country which is able to manufacture this instrument.

Congress did not provide any addition to the clerical force, and it is earnestly recommended that the additional clerks which will be requested in the estimates to be submitted by the superintendent for the next fiscal year be approved and Congress urged to allow the same.

The Supplement to the American Ephemeris for 1917, Tables Giving the Times of Rising and Setting of the Sun and Moon for 1917 and 1918, was received from the printer on January 18, 1917, and has been distributed. These tables have received very favorable comment. The Supplement to the American Ephemeris for 1918, Total Eclipse of the Sun, June 8, 1918, was received from the printer May 14, 1917, and is being distributed.

Work on the photographic zenith tube of observations for the determination of variation of latitude has been continued throughout the year.

The fundamental observations begun on May 29, 1916, with the 6-inch transit circle have been continued during the year.

A number of contributions were made by the members of the observatory staff to the Astronomical Journal. The asteroid observations made with the photographic equatorial have been forwarded for publication in that journal.

The replacement of old and unsafe wiring and lights in the main building was completed this year.

The routine work has been kept up without intermission during the year.

The distribution of publications has been carried on, issues of the American Ephemeris and Nautical Almanac made, the regular program of astronomical observations followed, the service supplied with nautical instruments, and a large number of visitors given an opportunity to view the heavenly bodies.

The observatory was closed to visitors for several months during this year owing to war conditions.

The instruments, buildings, and grounds have been kept in order.

The astronomical council, consisting of the superintendent and the heads of departments and divisions, has met each month to discuss the work of the observatory.

The scientific personnel has met twice each month, except during the summer, for the discussion of current astronomical topics and reading of papers by its members and scientists.

The astronomical work of this institution is now even more important than usual, owing to the European observatories losing many skilled observers due to the war.

The 14.449 acres of land owned by the Government to the eastward of the southern junction of Massachusetts Avenue with the Observatory Circle is still entirely unimproved.

The special work accomplished by the different departments and divisions is as follows:

DEPARTMENT OF COMPASSES, CHRONOMETERS, AND OTHER NAUTICAL, AERONAUTIC, AND SURVEYING INSTRUMENTS; THE TIME SERVICE; THE NAUTICAL INSTRUMENT REPAIR SHOP; INSPECTION AND SURVEY.

Commander W. D. MacDougall, United States Navy, continued as head of this department until August 16, 1916, when he was relieved temporarily by Lieut. Commander James P. Murdock, United States Navy. Commander George C. Day, United States Navy, was in charge of this department from January 15, 1917, to June 30, 1917.

Professor of Mathematics, H. E. Smith, United States Navy, continued in charge of the supply department.

Commander H. Kimmell, United States Navy, retired, continued as inspection and survey officer.

Lieut. Commander James P. Murdock, United States Navy, continued in charge of the Compass Office until March 3, 1917, when he was relieved by Lieut. Isaac C. Johnson, United States Navy, who continued in charge of the Compass Office until June 13, 1917, when he was relieved by Commander John S. Doddridge, United States Navy, retired.

Lieut. J. H. S. Dessez, United States Navy, continued as assistant in chronometers and other nautical instruments and time service to March 23, 1917.

Commander Charles T. Jewell, United States Navy, retired, reported at the Naval Observatory on March 2, 1917, and has been assistant in the nautical instruments and time service since March 23, 1917.

Mr. C. B. Watts continued as assistant in chronometers and time service, specially charged with care of timepieces in stock and trial, computations, and time-service apparatus.

TIME SERVICE.

Time signals were sent out from the observatory daily at noon and 10 p. m., seventy-fifth meridian time, over the wires of the Western Union Telegraph Co., and by direct wire to the Bureau of Standards and the wireless operating relay at Radio, Va.

Time signals are also sent out from the time and chronometer station at the Mare Island Navy Yard, Cal., over the Western Union lines to points on the Pacific coast, whence they are repeated by wireless.

The possibility of rating chronometers by accurate wireless time signals anywhere in the north Atlantic Ocean has made it possible to cut down to one the allowance of chronometers for vessels of the Navy operating only along the Atlantic coast.

The outbreak of war caused the dismantling of privately owned receiving sets all over the country. The number of requests for exemption coming in from watch manufacturers, jewelers, and scientific laboratories and observatories proved how popular the custom of receiving time signals by wireless has become.

The mean daily error of signals sent from the observatory for the year was 0.036 second, and the maximum error was 0.21 second.

Error is caused by a change in rate of the standard clock during cloudy periods, when observations of stars for time is impossible.

The error in correcting the transmitting clock to agree with the assumed error of the standard is never more than 0.02 second.

The new switchboard referred to in the last annual report has been installed and was first used on April 15.

CHRONOMETERS AND TORPEDO-BOAT WATCHES.

The following is the summary of the annual trial of chronometers and torpedo-boat watches, which began January 19, 1917, and ended July 2, 1917:

	Number in trial.	Number passing.
Chronometers:		
New American	33	15
New foreign		
Old	26	10
Torpedo-boat watches:		
New American	18	4
New foreign	33	10
Old	2	

The accompanying Tables I, II, III, give the data for those which passed.

During the year the following changes in the stock of navigational timepieces were effected:

	Chronometers.	Torpedo-boat watches.	Patrol-boat chronometers.
Purchased	33	30	20
Transferred from foreign vessels	9		
Cleaned or repaired—			
By makers	64	22	
By Naval Observatory	13	38	
Issued for use	136	55	

When circumstances permit, chronometers and torpedo-boat watches are withdrawn from service for cleaning and necessary repairs every four years. There are now only three firms in America who undertake this work. Chronometers are also cleaned and repaired at the Mare Island Yard and at the Naval Observatory. The observatory employs an expert in this line, and is in a position to handle the work expeditiously and cheaply, but in small numbers only. It is the policy of the observatory to give enough repair work to the commercial repairers to keep together their force of workmen and to keep up the standard of their work.

Due to the high cost of material and labor, the Bureau of Navigation has advanced the price to be paid in future for navigational timepieces.

American manufacturers of watches have not yet succeeded in producing in any quantity timepieces that will pass the test for torpedo-boat watches. Improvement is shown, and arrangements are being made to induce other manufacturers to compete.

The observatory has procured 20 watch movements mounted in chronometer bowls for use on board coast-patrol boats, and is negotiating for further purchases. The results have been gratifying.

CLOCKS AND WATCHES.

The increase in the Navy during the past three months has necessitated the purchase of large quantities of clocks and watches, all of which are tried at the observatory. To facilitate these trials an electric-driven watch-winding machine has been designed and is being manufactured.

There are now about 500 watches at the observatory under trial and arrangements have been made to test 450 clocks at one time.

Owing to the excessive number of stop watches returned for repairs, the observatory has been obliged to specify a high-grade watch for this purpose. No American watchmaker has undertaken to supply a watch of the necessary quality. The supply from abroad is limited. The Bureau of Navigation is therefore restricting the issue of stop watches to cases where they are absolutely necessary. The comparing watches issued are better timekeepers, more durable, and much cheaper than the stop watches.

An important advance has been made during the year by the purchase and issue of clocks for decks, bridges, officers' quarters, and boats, in which the hands and hour figures are painted with radium luminous material so as to be visible at night.

Aircraft are also being supplied with luminous clocks.

The large number of timepieces under trial makes necessary the use of devices for expediting comparisons. Such devices have been installed so that one employee is able to compare 540 watches or clocks per hour to the nearest second and 6 chronometers per minute to the nearest tenth of a second.

NAUTICAL INSTRUMENTS.

The nautical-instrument repair shop at the Naval Observatory has continued to prove economical in time and expense compared with the previous system of doing this work by contract.

During the fiscal year there were added to the original shop force of 9 men the following: October 16, 1 box maker (packer); April 23, 1 box maker (packer); April 24, 1 general helper, making a total of 12 men employed in the shop at the end of the year.

The quality of the work done compares favorably with that of the best commercial instrument makers, and the saving in time and cost is very great. Navigational instruments can generally be delivered in from 3 to 5 days after receipt, deck and boat clocks in 3 weeks, chronometers and torpedo-boat watches within 30 days.

It has been found by trial that chronometers and torpedo-boat watches repaired in the shop receive trial numbers as low as those repaired by commercial firms. In view of the excellence of his work, it is recommended that the pay of the chronometer maker be increased to about $5 per diem.

Attention is invited to the large number of instruments that have been reconstructed from junk. Since the custom has prevailed of sending to the Naval Observatory parts of instruments condemned by survey it has been found possible to combine these parts, sometimes with additional new parts, and to turn out instruments fit for service. Sixty sextants have been manufactured in this way, and numerous binoculars and spyglasses have been repaired by using parts of condemned glasses.

A dividing engine has been ordered. When this is received, additional reconstruction work can be accomplished. It is not possible at this time to regraduate the scales of sextants, stadimeters, mercurial barometers, etc.

Plans and specifications have been made for an enlargement of the shop building. Congress appropriated $20,000 for this purpose. Upon sending our proposals for the work bids were submitted 50 per cent greater than the appropriation. Efforts are now being made by the Bureau of Yards and Docks to obtain the needed additional money.

During the year repairs have been made to navigational and surveying instruments in numbers and at the cost as given in the following list:

Instruments.	No.	Cost.	
		Total.	Average.
Anemometers	1	$1.56	$1.56
Alidades	27	288.98	10.70
Azimuth circles	79	727.76	9.19
Artificial horizon	1	3.66	3.66
Barographs	1	1.20	1.20
Barometers:			
Aneroid	81	345.46	4.26
Mercurial	34	437.29	12.81
Binoculars:			
Day	90	427.09	4.74
Night	148	787.85	5.32
Prismatic	132	1,170.61	8.87
Chronometers	22	388.76	17.67
Chronometer cases	78	18.47	.24
Clinometers	31	140.62	4.54
Compasses, pocket (aero)	7	38.72	5.53
Clocks:			
Deck No. 1	118	484.58	4.11
Engine-room	70	357.29	5.10
Deck No. 2	127	475.81	3.75
Deck No. 3	30	99.22	3.31
Boat	74	341.68	4.62
Compass readers	8	51.22	6.40
Universal drafting machine	1	8.72	8.72
Heliograph	1	20.77	20.77
Drawing instruments	22	57.36	2.61
Levels	1	.78	.78
Magnetic sets	2	17.56	8.78
Magnetometers	1	7.50	7.50
Mirrors resilvered:			
Azimuth circle	77	17.79	.23
Sextant	723	144.78	.20
Stadimeter	148	26.88	.18
Octants	74	410.79	5.55
Parallel rulers	63	22.70	.36
Pelorus	18	54.68	3.04
Plane tables	1	2.40	2.40
Protractors, 3-arm	28	246.76	8.81
Psychrometers	14	29.59	2.11
Reading glasses	24	24.49	1.02
Sextants:			
High-grade	69	809.33	11.72
Surveying	103	1,190.43	11.56
Splines and weights	1	1.09	1.09
Spyglasses:			
High power	58	345.89	5.96
Medium power	53	293.56	5.54
Low power	60	314.91	5.25
Officer of the deck	167	668.00	4.00

Instruments.	No.	Cost.	
		Total.	Average.
Stadimeters	46	$714.21	$15.52
Telescopes, ship's	11	184.39	16.76
Tide gauges	2	8.95	4.48
Theodolites	17	367.30	21.61
Thermometers	2	2.16	1.08
Watches:			
Comparing	104	412.42	3.97
Stop	121	705.69	5.83
Torpedo-boat	52	185.17	3.56
Miscellaneous	28	227.32	
Total	3,251	14,112.50	

Charged to appropriations:

Ocean and lake surveys	$1,018.67
Engineering	314.56
Aeronautics	66.53
Naval Observatory	77.98
United States Geological Survey	214.70
	1,692.44
Instruments and supplies	12,420.06
	14,112.50

Grand total: Instruments, 3,251; labor, $9,910.70; indirect, $1,981.28; material, $2,220.52; total, $14,112.50.

Approximate total value of the instruments repaired, omitting miscellaneous shop equipment and observatory items, is $105,791.70.

The corresponding items for the fiscal year 1916 are: Number of instruments, 2,554, and cost of repairs, $11,324.94. This shows an increase of 37 and 41 per cent, respectively, over last year's work.

COMPASS OFFICE.

Gyro-compasses.—During the year the development of the Sperry gyro-compass has continued, and, in addition to the battleship and submarine installations, a new type of gyro-compass, consisting of two rotors, has been developed for use on destroyers. The installations of this type had not been made at the close of the year. In all the larger type submarines, beginning with the *Schley*, *60*, and *61*, and the R and S classes, the duplex system is to be installed.

The school maintained by the Sperry Gyroscope Co. has proved invaluable in supplying the service with trained gyro men, and the results are shown in the increased efficiency of the compass.

Magnetic compasses.—Owing to the outbreak of the war, it has been necessary to largely increase the stock of magnetic compasses and equipment. These increases were covered by requisition as early as possible.

Air compasses.—The Sperry types of air compass with horizontal card and with vertical card have been tried out at the aeronautic station at Pensacola for seaplanes. The vertical type card is recommended.

Azimuth circles, peloruses, etc.—Bearing instruments have been supplied during the year and several types of azimuth circles have been tried.

The following extract from a memorandum submitted by the compass office to the Bureau of Equipment on January 15, 1906, is given:

> At the time when the Navy was composed principally of wooden ships and the introduction of steel ships was just beginning, the compass office force consisted of two or more officers with adequate clerical assistance. All reports were carefully considered and filed. Considerable original research was carried out. Compass manuals, up to date, were prepared and issued to the service. With the increased size of the ships, the increased number of compasses installed, and the great increase in compass equipment required, the more complicated the problem of the magnetic compass and the requirements of the battle compass below deck became, the compass office facilities have been decreased in almost direct proportion to the increase in difficulty and importance of this work, until at the present time but one officer is attached to the compass office, who is practically without clerical assistance.
>
> As a necessary result of this condition, the officer in charge of the compass office has been compelled to a greater and greater extent to devote his time to the question of compass material, and the second of his functions, to scrutinize the reports from ships and see that the proper reports were written, has been relegated to second place.

Since the above report was written the gyro-compass and its equipment has been added to the duties of this office, while the magnetic compass work, if properly carried out, has steadily increased. This condition has resulted in the inability of the compass office to scrutinize and read reports of both gyro and magnetic compasses. It is recommended that proper clerical force be allowed this office as soon as practicable.

AVIATION INSTRUMENTS AND EQUIPMENT.

As noted in the last annual report, the year started without any instruments or equipment for aviation, under the cognizance of the Bureau of Navigation, having been standardized.

Sets of clothing as used in the British and French aviation services were inspected at the observatory and at the aeronautic station at Pensacola, as well as sets manufactured by American firms. A board was appointed at Pensacola to specify a standard equipment, and their report has been approved. The Bureau of Supplies and Accounts now has specifications for standard articles of clothing and personal equipment approved by the department, and is engaged in the purchase and issue of this material.

In conjunction with the station at Pensacola and other commands engaged in flying, the observatory has practically accepted as standard an altimeter (altitude aneroid barometer) and a clock. A compass for aircraft has been adopted and issued, but is not proving entirely satisfactory and further experiments are under way.

One form of statoscope for dirigibles has been found satisfactory for certain purposes, and will be issued to each dirigible when delivered. This is the Custer type. This instrument is nonluminous and does not indicate speed or amount of change of height. The observatory is assisting various inventors and makers of instruments to devise a statoscope that will answer all requirements.

The observatory has on hand a small number of aeroplane cameras of acceptable design. These are not fixed in the car, and their value will have to be determined in service. Other forms of camera are under trial.

Several barographs, for trial flights of aircraft, have been purchased which are acceptable in design, but generally unsatisfactory in workmanship.

A clamping device for aviators' binoculars has been designed at the observatory, which meets the approval of the service, but, owing to the congested condition of the optical factories, has not been supplied to the service.

A buzzer type masthead anemometer has been adopted as standard. These are to be issued not only to aviation ships and stations, but also to battleships for assisting in determining the initial sight-bar range and deflection for fire control.

Instruments of the following types have been examined at the observatory or at Pensacola:

Compasses: Creagh-Osborne, English make; Creagh-Osborne type, Sperry Gyroscope Co.; Sperry, horizontal card, aviation compass.

Altimeters: Taylor instrument companies, 10,000, 12,000, 15,000 feet maximum altitude; silver dials, silver dials with luminous figures, black dials, luminous.

Altimeters (aneroid barometers): Pocket size, Covelle, Hunter Hoecker, Hicks, Short & Mason.

Barographs: Richard, Green, Taylor, Schneider.

Barographs, pocket: Richard.

Clocks: Chelsea aeroplane clock.

Cameras: Herbert & Huesgen, Mueller, Eastman, type A; Eastman, type B.

Anemometers, masthead: Green (recording), Kadel (buzzer).

Anemometers, portable: Davis, Keuffel & Esser.

Statoscopes: Custer, Schneider (two types), Sprengnether nonautomatic, Sprengnether automatic, Hue, Richard, Rojas.

Blish dip prism.

Sperry drift indicator (two types).

G. E. M. ground speed meter.

In all, 35 different types of aviation instruments.

Arrangements have been made with the War Department for the supply of two Brock aero cameras.

The following aviation instruments have been issued to the service: 52 altimeters, 18 barographs, 8 clocks, 44 compasses, 14 statoscopes, 9 anemometers (masthead), 10 anemometers (portable).

SUPPLY DEPARTMENT.

Prof. H. E. Smith, United States Navy, continued as head of this department during the year, with Mr. H. G. Hodgkins, assistant in the department of nautical instruments, as assistant.

A brief statement of the year's work for this department follows:

Value of stock on hand July 1, 1916	$130,723.09
Value of instruments. etc., purchased	191,512.54
Value of instruments received from yards and ships	29,534.59
Value of instruments issued and expended	235,559.58
Value of stock on hand July 1, 1917	116,210.64
Number of shipments made (an increase of 758 over 1916)	2,225
Number of instruments and parts shipped (an increase of 10,057 over 1916)	16,274
Number of shipments received (an increase of 615 over 1916)	1,040
Number of instruments and parts received (an increase of 24,814)	37,968

INSPECTION AND SURVEY.

During the year the following new instruments were inspected and passed: 15 azimuth circles, 1,657 prismatic binoculars, 121 day binoculars, 772 night binoculars, 20 ships' telescopes, 100 low-power spyglasses, 900 officer of the deck spyglasses, 25 sextants, high grade, 100 stadimeters, 307 aneroid barometers, 481 sextant and stadimeter mirrors, 14 Battenburg course protractors, 200 Koch protractors, 690 navigators' dividers; 50 clinometers, 53 compass-reading glasses, 1,447 parallel rulers, 20 sets of splines and weights.

All material and tools for the repair shop have been inspected as to quantity and quality, and all the repair work of the shop inspected. This has increased greatly during the year; 241 sextants were tested for eccentricity during the year.

Spare sextants and other instruments have been returned from the larger ships and navy yards for issue to smaller vessels. These have been surveyed and are being repaired as fast as possible.

DEPARTMENT OF THE NAUTICAL ALMANAC.

This department has continued under the direction of Prof. W. S. Eichelberger, United States Navy.

The Supplement to the American Ephemeris for 1917, Tables Giving the Times of Rising and Setting of the Sun and Moon, 1917 and 1918, was received from the printer on January 18, 1917.

The American Ephemeris and Nautical Almanac for 1919 was received from the printer on March 7, 1917.

The Supplement to the American Ephemeris for 1918, Total Eclipse of the Sun, June 8, 1918, was received from the printer on May 14, 1917.

The American Nautical Almanac for 1919 was received from the printer on May 28, 1917.

Astronomical Papers of the American Ephemeris, Vol. IX, Part II, New Elements of Mars and Tables for Correcting the Heliocentric Positions derived from Astronomical Papers, Vol. VI, Part IV, by Frank E. Ross, was received from the printer on May 31, 1917.

The complete copy of the American Ephemeris and Nautical Almanac for 1920 has been sent to the printer and 535 pages are in type.

Thirty-two pages of the American Ephemeris and Nautical Almanac for 1921 are in type.

The following assistants and pieceworkers were employed in preparing for publication the annual volumes of the American Ephemeris and Nautical Almanac: Assistants, James Robertson, William T. Carrigan, Arthur Snow, Arthur Newton, Perez Fisch, George F. Crawley, Clifford S. Lewis, Joseph J. Arnaud, Frank Langellotti, Reuben Weinstein, and Morris Liferock; pieceworkers, Elizabeth B. Davis, Janet McWilliam, Hannah F. M. Hedrick, Alfred Doolittle, George B. Merriman, and Isabel M. Lewis.

The investigation of the orbits of Saturn's satellites has been continued. Forty-eight sets of corrections to the elements have been obtained from 9 pairs of satellites covering 12 oppositions. All these corrections depend upon observations made at Washington from 1895 to 1908, except two sets depending on Lick observations. The normal equations have been formed for the determination of five additionl sets of corrections from Lick observations, and equations of condition for 46 more sets. Work has been started in comparing with theory the observations made at Washington during the years 1909 to 1916.

The work of obtaining new orbits of the seventh satellite of Jupiter and the satellite of Neptune has been continued.

The following assistants and pieceworkers were employed on the various pieces of the above-mentioned work of improving the tables of the planets, moon, and stars: Assistants, William T. Carrigan, Walter M. Hamilton, Arthur Newton, Perez Fisch, George F. Crawley, Joseph J. Arnaud, Frank Langellotti, Reuben Weinstein, and Morris Liferock; pieceworkers, Elizabeth B. Davis, Janet McWilliam, Hannah F. M. Hedrick, Henry B. Hedrick, Thomas E. Trott, Louis Lindsey, and Isabel M. Lewis.

DEPARTMENT OF ASTRONOMICAL OBSERVATIONS.

DIVISION OF 6-INCH TRANSIT CIRCLE.

The personnel of this division consisted of Assistant Astronomer J. C. Hammond (in charge), Assistant Matt Frederickson, and Assistant C. C. Wylie.

The observations, begun on May 29, 1916, have been continued during the year in accordance with the plan outlined in the report for 1916. The observing list comprises the Sun, Mercury, Venus, 152 fundamental stars selected from the American Ephemeris and Boss, and certain miscellaneous stars. This instrument is also used for the determination of time for the time service.

The number of observations secured during the year is as follows:

Clock stars	1,712
Time stars	520
Pole stars	335
Refraction stars	148
Day-night stars	616
Miscellaneous stars	670
Inclination stars	265
Sun	101
Mercury	40
Venus	20
Total	4,427

The number of determinations of instrumental constants is as follows:

Collimation	560
Level:	
Spirit	14
Nadir	597
Marks	581
Nadir	603
Runs	30
Flexure:	
Horizontal	14
Vertical	6
Total	2,405

The instrument was reversed 16 times and the stellar focus adjusted twice during the year.

The magnitude equations of the three observers, corresponding to a diminution of three magnitudes in the brightness of a star, were determined in February, 1917, with the following results:

Observer.	*Bright—faint.*
Hammond	$-0^{s}.0004$
Frederickson	$-$ .0004
Wylie	$-$ .0010

These results are the means of over 100 stars for each observer, about 35 stars being observed on each of three nights.

In June, 1917, the micrometer and objective were interchanged and the circle rotated on its axis so as to read 330° 54′ on the nadir. Previous to this, the objective was removed from its cell and cleaned by Assistant G. H. Peters. Also the errors in the screws of the micrometer were measured by the observers. These errors are small and a periodic error in the zenith distance screw, as shown by measures in 1911, seems to have disappeared.

CLOCK VAULT.

The temperature in the clock vault has been maintained practically constant at 84° F. during the year. Riefler clock No. 60 was used as the standard clock during the year, with the exception of the period from August 5 to November 8, 1916, when it was being cleaned and rated. During this period Riefler No. 70 was the standard clock.

The following table gives the mean daily rate of the standard clock as deduced by the time service, together with the maximum variation in the rate for each month:

Month.	Mean daily rate.	Maximum variation.	Clock No.	Month.	Mean daily rate.	Maximum variation.	Clock No.
1916.				1917.			
July	$-0^{s}.06$	$0^{s}.12$	60	January	$-0^{s}.07$	$0^{s}.06$	60
August	+.19	.09	70	February	−.09	.04	60
September	+.26	.13	70	March	−.11	.04	60
October	+.31	.08	70	April	−.11	.05	60
November	−.03	.05	60	May	−.14	.04	60
December	−.05	.03	60	June	−.16	.07	60

Total variation in daily rate during the year: No. 60, 0.19 second; No. 70, 0.20 second.

DIVISION OF 9-INCH TRANSIT CIRCLE.

The personnel of this division consisted of Assistant Astronomer Herbert R. Morgan (in charge), Assistant Jesse Pawling, Assistant Leroy P. Steele to May 31, 1917, and Miscellaneous Computer Paul Sollenberger.

The observations of the intermediary and standard stars, begun August 1, 1913, have been continued, and two observations have now been made of all but about 300 stars of the list.

The number of observations made during the year is as follows:

Intermediary stars	2,910
Standard stars	1,380
Clock stars	1,842
Azimuth stars	245
Refraction stars	41
Reflection stars	192
Moon	74
Jupiter	15
Saturn	15
Uranus	16
Neptune	15
Total	6,745

The total number of observations since the beginning of this work is 30,239.

The measures of the pivots taken in July agree with those previously taken. The instrument was reversed four times during the year, and the number of determinations of the instrumental constants is as follows:

Collimation	498
Level:	
Nadir	624
Spirit	135
Azimuth (marks)	628
Nadir	636
Flexure:	
Horizontal	14
Vertical	12

On the time not spent in observing the members of this division have made the following reductions: The chronograph records are read and means in observing books taken to date; the azimuth of the marks, all instrumental constants, and the clock star reduction sheets have been computed for the year ending August, 1916; the preliminary clock corrections have been derived for the two years ending August, 1916; the observations have been copied on the sheets, and the declination reductions begun for the year ending August, 1914.

DIVISION OF THE EQUATORIALS.

The personnel of this division consisted of Prof. Asaph Hall, United States Navy (in charge); Assistant George H. Peters; Assistant H. E. Burton; and Assistant E. C. Bower.

Observations were taken as follows:

26-INCH EQUATORIAL.

Comets	25
Occultations	41
Arcs for micrometer screw	119
Asteroids	4
Instrumental constants	2

Of the comet observations, 17 were of 1916b (Wolf), 2 of 1917a (Mellish), and 6 of 1917b (Schaumasse). The 4 asteroid observations were of (288) Glauke, for the Bilk Observatory.

In September the Repsold micrometer was removed from the instrument and was taken apart and cleaned and oiled. It was in excellent condition. A number of new spider lines were inserted by Mr. Reinbold, of the nautical instrument shop. At the same time the driving clock of the 26-inch equatorial was taken apart and cleaned by Mr. Cleve, the observatory instrument maker.

In May further examination was made of the screw of the Repsold micrometer by means of the eyepiece microscope and the auxiliary threads. The errors appear to be small enough to be neglected.

From the observations of arcs a definitive value was computed of a revolution of the screw of Clark Micrometer II. It is: $R=9''.9329+0''.000052$ (T–50° F.). This holds for the period May 20, 1908, to June 14, 1915, and for the focal setting 1.280. The periodic errors of the screw of Clark II are negligible. In the measures of the satellites of Saturn the progressive errors are also negligible when double distances are observed. However, beginning with the opposition of 1909–10, the progressive errors of the screw of Clark II have been applied in the reduction of the satellites of Saturn.

In accordance with the decision of the astronomical council, approved by the superintendent, the observations with the 26-inch and 12-inch equatorials have included only occultations, comets, and asteroids of special interest, and observations for instrumental constants. But as much time as possible has been given to the reduction and preparation for publication of the observations which have accumulated. The observations of the satellites of Saturn for six oppositions are to be turned over to the Nautical Almanac Office. Of the combinations in pairs the Equatorial Division is to discuss four, after the places corresponding to the times of observation have been computed from the tables of Evans and after the differential coefficients have been formed in that office.

The observations of Saturn's satellites for four oppositions have been transmitted to the Almanac Office.

12-INCH EQUATORIAL.

With this instrument 38 occultations were observed; also there was made one observation of Comet 1917 a (Mellish).

One thousand and thirty-six visitors were shown through the 12-inch Equatorial by Mr. Peters and Mr. Burton. After February, 1917, the observatory was closed at night to visitors.

In July low-voltage lamps were placed on the 12-inch, to be used in connection with a small transformer.

Observations have been published in the Astronomical Journal as follows:

Satellite VI of Jupiter, 1912–1915, inclusive.
(433) Eros, 1914–15.
(624) Hektor, 1915.
(796) 1914 V H.
Comet 1914 c (Neujmin), through July 28, 1914.
Comet 1914 c (Campbell), through November 19, 1914.
Comet 1915 a (Mellish), through January 18, 1916.
Comet 1915 e (Taylor), through March 31, 1916.
Comet 1916 a (Neujmin), through May 5, 1916.
Comet 1916 b (Wolf), through May 1, 1917.
Comet 1917 a (Mellish), through March 30, 1917.

Comet 1917 b (Schaumasse), through May 18, 1917.

Also there was published in the Astronomical Journal a compilation of positions of pairs of stars used for values of equatorial micrometer screws.

PHOTOHELIOGRAPH.

Photographs of the sun have been made on 186 days, and solar spots or groups found on 181 days. The indications are that we have arrived at the sun-spot maximum.

PHOTOGRAPHIC TELESCOPE.

The photographic telescope has been in continuous use by Mr. Peters during the year, and has been employed principally in the observation of asteroids.

Observations are made in the following zones:

+ 4° to + 8°—March, April, September, October.
0° to + 4°—May to August.
+12° to +16°—November to February.

With few exceptions, all asteroids in these zones which are given in the Berliner Jahrbuch have been observed or searched for. Those in the following list have been found. The observations through 1916 have been sent to the Astronomical Journal.

Two photographs of Prof. Barnard's large proper motion star have been made for measurement, and further observations will be secured.

Asteroid.	Number of observations.	Asteroid.	Number of observations.	Asteroid.	Number of observations.
17 Thetis	2	173 Ino	2	380 Fiducia	2
18 Melpomene	2	194 Prokne	2	401 Ottilia	2
32 Pomona	2	201 Penelope	2	407 Arachne	2
37 Fides	2	213 Lilaea	2	409 Aspasia	2
58 Concordia	2	219 Thusnelda	2	441 Bathilde	2
60 Echo	2	241 Germania	2	442 Eichsfeldia	2
78 Diana	2	245 Vera	10	447 Valentine	2
86 Semele	2	257 Silesia	2	455 Bruchsalia	2
92 Undina	2	268 Adorea	2	489 Comacina	2
102 Miriam	2	303 Josephina	2	532 Herculina	3
115 Thyra	2	305 Gordonia	2	536 Merapi	5
119 Althaea	2	308 Polyxo	2	538 Friederike	2
122 Gerda	4	334 Chicago	5	572 Rebekka	2
129 Antigone	2	335 Roberta	2	584 Semiramis	2
130 Elektra	2	358 Apollonia	2	714 1911 LW	1
131 Vala	1	371 Bohemia	2	723 Hammonia	2
133 Cyrene	2	374 Burgundia	2	742 1913 QU	2
145 Adeona	2	378 Holmia	2	785 1914 UN	2

DIVISION OF PHOTOGRAPHIC ZENITH TUBE AND ALT-AZIMUTH.

This division has been in charge of Prof. F. B. Littell, United States Navy, who has been assisted in the observational work by Assistant Astronomer G. A. Hill.

PHOTOGRAPHIC ZENITH TUBE.

Observations for the determination of the variation of latitude have been made throughout the year. The observing list consists of 64 stars divided into 8 groups of 8 stars each, with 7 additional stars for scale value. These stars culminate within 10½ minutes of the zenith, and the mean zenith distance of each group is made as small as practicable by balancing north and south stars. Usually two groups are observed the same night unless weather conditions prevent. At certain times of the year, however, three groups are on the program.

The number of star observations secured during the year was 1,537. The reduction of these stars is well advanced, using preliminary declinations for the stars. These stars have been observed recently with the 6-inch transit circle, and as soon as the resulting declinations are available the definitive results of the work for the variation of latitude can be obtained.

ALT-AZIMUTH.

The alt-azimuth has been used in connection with the photographic zenith tube, the observer utilizing the intervals between the observations with the latter instrument to secure declination observations with the former. The stars on the observing list are those of the Liste Générale Provisoire d'Étoiles Fondamentales contained in the Supplément à la Connaissance des Temps pour l'An 1914, culminating within 75° of the zenith. The work of the photographic zenith tube prevents this list from being completely observed.

The instrument is used in the meridian as a quickly reversible meridian circle, each star being observed in both clamps at the same culmination. The telescope micrometer and the microscopes are provided with reversing prisms. The alidade has three levels.

The number of observations secured during the year was 1,294.

Minor changes have been made in each of the instruments during the year, adding to the convenience and accuracy of observing.

DIVISION OF PRIME VERTICAL TRANSIT INSTRUMENT.

This division has been in charge of Assistant Astronomer George A. Hill.

During the past year observing with the instrument has been suspended.

A large number of tables containing data to be published, and which were mentioned in the last annual report, have been examined, checked, and put in form for printing.

They consist of the individual observations copied from the cards, means taken, and arranged in order of right ascension. The individual latitudes of the instrument, resulting from all stars for which a definite declination and proper motion is known, have been put in form for publication after having been examined and checked. This latter table contains about 7,000 separate latitude determinations.

Much study has been given in preparing definitive declinations and obtaining proper motions for 15 of the 16 stars that were used in observing by the polygon method. When the stars were selected in 1904 some of them were lacking in good star catalogues of epoch after 1890, and others were weak in number of known places prior to that. That condition arises by the fact that in selecting the stars their positions in the sky was a prominent factor in the selection, and prevented securing stars whose places had been well determined.

In consequence the proper motions of some of them were not at that time well determined. Careful search has been made in modern catalogues and has resulted in recent material that has been included in a recomputation for better proper motions for each star.

A discussion has been made during the year of the proper motion of α Lyrae, based upon about 1,800 observations of the star made between 1893 and 1912. The result of the same suggests a larger proper motion for that star than was used at the commencement of the series. This larger proper motion brings the places, when reduced to 1900, into better accord.

Progress has been made in the preparation of manuscript explanatory of the reductions and results secured.

Preliminary solutions have been made for the correction to the Constant of Aberration used in the series, from 1904 to 1912, inclusive.

An examination of the material has been made to ascertain if in observing in the prime vertical there is indicated a personal equation depending upon magnitude. The result of that discussion is not yet finished.

While the instrument is out of use it is protected by a covering and inspected each week as to its condition.

DIVISION OF REDUCTION OF OBSERVATIONS.

This division has been in charge of the executive committee. The personnel consisted of Assistant Eleanor A. Lamson; miscellaneous computers William A. Conrad, R. R. Candor, S. Goldstein (until Mar. 1, 1917, resigned), L. P. Steele (from June 1, 1917), William Katz (from June 1, 1917), L. A. J. Rabinowitz (from June 19, 1917), R. D. Gustin (from Mar. 16 to Mar. 31, 1917, temporary), F. E. Swindells (from May 21, 1917, temporary), Elizabeth W. Wilson (from May 26 to June 15, 1917, temporary), D. B. Brooks (from June 12, 1917, temporary), M. R. Malone (from June 14, 1917, temporary).

REDUCTION OF THE 9-INCH TRANSIT CIRCLE WORK, 1903–1911.

The discussions mentioned in the last annual report for the introduction to Part I, Volume IX, second series, Publications of the United States Naval Observatory, have been completed while the introduction itself is almost ready for the printer. The printer's copy of the catalogue has been formed.

Part III, Volume IX, second series, Publications of the United States Naval Observatory, comprising the journal of observations from October 6, 1908, to April 10, 1911, is in plate.

REDUCTION OF THE 9-INCH TRANSIT CIRCLE WORK, 1912–13.

This work, which comprises the reduction of observations extending over the period January 31, 1912, to April 19, 1913, has been completed and the catalogue formed. The major portion is in plate and when printed will be known as Part IV, Volume IX, second series, Publications of the United States Naval Observatory.

WASHINGTON-PARIS LONGITUDE WORK.

The Appendix to Volume IX, Second Series, Publications of the United States Naval Observatory, which contains the details of the Washington-Paris longitude determination 1913–14, has been issued in the form of reprints during the year. It is about ready for binding as appendix in the regular volume of the observatory publications, which will also contain Part III (the journal of observations of the 9-inch transit circle, Oct. 6, 1908, to Apr. 10, 1911), and Part IV (the introduction, journal of observations and catalogue of the 9-inch transit circle, Jan. 31, 1912, to Apr. 19, 1913).

REDUCTION OF THE 6-INCH TRANSIT CIRCLE WORK.

This work, which comprises the right ascension and declination reduction of observations, from May 15, 1911, to August 11, 1913, and the declination reduction of observations from July 23, 1915, to June 1, 1916, is well advanced.

REDUCTION OF PHOTOGRAPHIC ZENITH TUBE WORK.

The latitudes from the individual observations have been deduced from October 27, 1915, to December 31, 1916, using preliminary values of the declinations of the stars. The reductions from January 11, 1917, to March 31, 1917, are well advanced.

LIBRARY.

Mr. W. D. Horigan continued as librarian throughout the year.

	Volumes.	Pamphlets.	Total.
Contents of library July 1, 1916	28,786	5,704	34,490
Accessions:			
By purchase	204	....	204
Through exchange	267	60	327
Total	29,257	5,764	35,021

The following publications were printed:

	Copies.
Annual Report of Naval Observatory, 1916	1,200
Publications, Naval Observatory, Vol. IX, Appendix	1,200
Table of Factors for the reduction of Transit Observations	100
American Ephemeris, 1919	1,300
American Nautical Almanac, 1917	1,000
American Nautical Almanac, 1919	1,500
Tables giving the times of rising and setting of the sun and moon, 1917 and 1918 (Supp. Amer. Ephem., 1917)	2,000
Total Eclipse of the Sun, June 8, 1918 (Supp. Amer. Ephem., 1918)	1,500
Astronomical Papers of the American Ephemeris, Vol. IX, part 2	1,000

There were distributed 1,801 publications of the department of astronomical observations and 5,327 publications of the department of the Nautical Almanac, making a total of 7,128 copies.

BUILDINGS, GROUNDS, AND ROADS.

Prof. H. E. Smith, United States Navy, has had charge of buildings, grounds, and roads in addition to his other duties during the year.

The 53 buildings constituting the Naval Observatory plant are in good condition. During the fiscal year repairs as follows have been accomplished:

PAINT (OUTSIDE WORK).

Great equatorial dome and all woodwork.
Barn and entry way.
Whitewashed cart house and painted tools.
Alt-azimuth building.
Photo-zenith building.
West transit meridian mark.
Instrument repair shop roof.
Photo-equatorial roof.
Longitude buildings and their meridian marks.
Porch, superintendent's house.
Outside woodwork, superintendent's house.
Outside woodwork, boiler house.
Lane fences.
Flagstaff stays.
Lane entrance gate.
All lamp posts.
Gate house.
New clock vault.
Transit testing house.

PAINT (INSIDE WORK).

Whitewashed inside of barn.
Basement, superintendent's house.
Three rooms in observers' quarters.
Temperature room.
Toilet room.
Superintendent's office.
Time room.
Compass room.
Library.

REPAIRS TO BUILDINGS.

All copper, tin, and slate roofs repaired.

All down spouts and eave troughs repaired.

Replaced old electric wiring in basement of main building in metal conduits. Wiring in main building now meets the approval of the National Board of Fire Underwriters.

Replaced old electric wiring and fixtures under clock house and put in metal conduits.

Prepared south transit building for temporary shop to be used while addition is made to the permanent shop building.

Plastered several rooms in superintendent's house.

Overhauled and repaired all screens.

Built scaffolds for painter's use.

Repaired greenhouse benches.

Relaid floor in basement in superintendent's house.

Made various repairs on observers' quarters.

Repaired all shingle roofs.

Repaired elevator and equatorial gear.

GROUNDS.

Fertilized lawns where necessary.

Sowed grass seed on bare spots.

Cleared out dead trees and dead wood from trees.

Kept lawns and shrubbery trimmed.

Repaired boundary fences and hedges.

Replaced several dead shade trees.

Cleared drains, sewers, etc., where necessary.

Replaced topmast for flagstaff (old one struck by lightning).

Did necessary digging to place electric cable beneath alt-azimuth and west transit houses.

Replaced obsolete fire hydrants with modern hydrants, identical with those used in the District.

Overhauled fire equipment.

Planted and kept up flowers in the usual beds.

Removed old wire fence back of garden and used wire to repair pasture fence.

Built 780 feet of iron tube fence on west side of lane.

Placed marks at boundary stones east of Massachusetts Avenue.

Built manure pit at barn.

Felled and split into cordwood numerous dead trees.

Cleared away brush in southern part of circle.

Raked and burned all dead leaves.

Cleared walks of snow, etc.

Built iron grape trellis.

Filled gulley east of lane.

Tore down old watering trough and cleared stream.

Removed three 2-ton piers from clock house.

Tamped all surface and drainage gutters.

Dug up garlic and dandelions from lawns.

Filled depressions in lawns with soil.

WALKS AND ROADS.

Repaved 2,000 feet of gutter, resetting stone in tarvia.

Put stone on all roads.

Resurfaced 2,000 linear feet of roadway with tarvia and stone.

Rolled all roads.

Laid 480 feet of concrete walk 4 feet wide from barn to the north gate.

Built several hundred yards of new roadway.

INSPECTIONS.

Made monthly inspections of all roofs, steam, water, air, and gas lines, conduits, waterways, drains, fire, flushing systems, buildings, and grounds.

Current repairs were made and routine work carried on. Plans and specifications were gotten out for an addition to the instrument-repair shop, in accordance with an appropriation of $20,000 for this purpose made by Congress in the first regular session in 1917.

As previously stated, the European observatories being more or less cripped by war conditions, additional responsibility is thrown on this observatory and the Nautical Almanac Office.

T. B. HOWARD,
Rear Admiral, United States Navy (Retired).

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TABLE I.—*Data of tr* (*Specifications 18C7a, Dec. 1, 1913.*)

omitted.]

Order of merit.	Balance: o=ordinary. v=invar. Hairspring: p=palladium. s=steel. Chronometer.		Ki	Ordinary temperatures. n not changed.			XII, East.	XII, West.	XII, North.	XII, South.
	Temperature			62.6	65.9	65.6	69.5	71.0	70.3	74.3
	Relative humidity			64	61	72	68	65	63	60
				May 14 to 21.	May 21 to 28.	May 28 to June 4.	June 4 to 11.	June 11 to 18.	June 18 to 25.	June 25 to July 2.
				s	s	s	s	s	s	s
1	Bliss....	3183	M.	+0.46	+0.27	+0.31	+0.39	+0.57	+0.56	+0.67
2	Bliss....	3180	M.	+0.44	+0.50	+0.36	+0.24	+0.23	+0.23	+0.14
3	Bliss....	3195	M.	−1.77	−1.93	−2.06	−2.01	−2.14	−2.20	−2.40
4	Bliss....	3182	M.	+2.23	+2.11	+2.16	+2.00	+1.86	+2.07	+1.33
5	Bliss....	3184	M.	+0.63	+0.63	+0.80	+0.74	+0.83	+0.97	+1.07
6	Negus...	2263	M.	+0.29	+0.43	+0.59	+0.69	+0.77	+0.84	+0.87
7	Negus...	2260	M.	+3.29	+2.90	+3.11	+3.50	+3.63	+3.73	+3.56
8	Bliss....	3186	M.	−2.83	−2.44	−2.46	−2.74	−2.64	−2.80	−2.89
9	Bliss....	3181	M.	+0.93	+0.96	+0.99	+0.84	+0.84	+0.87	+0.87
10	Negus...	2254	M.	−1.60	−1.51	−1.37	−1.24	−1.17	−0.94	−0.83
11	Bliss....	3191	M.	−2.17	−2.00	−1.91	−2.01	−2.04	−2.03	−2.13
12	Negus...	2262	M.	−2.60	−2.84	−2.84	−2.64	−2.44	−2.77	−2.76
13	Bliss....	3188	M.	−0.83	−0.59	−0.41	−0.29	−0.17	−0.20	−0.04
14	Negus...	2235	M.	−2.77	−2.57	−3.03	−2.86	−2.29	−2.17	−1.83
15	Negus...	2236	M.	−3.03	−2.71	−3.41	−3.30	−3.20	−3.10	−3.00

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TABLE II.—*Data of* trY. (*Specifications 18 W4a, Dec. 1, 1913.*)

n 25 omitted.]

		Ordinary temperatures.							
		n not changed.				XII, East.	XII, West.	XII, North.	XII, South.
Temperature		1	62.6	65.9	65.6	69.5	71.0	70.3	74.3
Relative humidity			64	61	72	68	65	63	60
Order of merit.	Balance: o=ordinary. v=invar. Hairspring: p=palladium. s=steel. Watch.	y	May 14 to 21.	May 21 to 28.	May 28 to June 4.	June 4 to 11.	June 11 to 18.	June 18 to 25.	June 25 to July 2.
			s	*s*	*s*	*s*	*s*	*s*	*s*
1	Leroy	43	+1.47	+1.50	+1.40	+1.53	+1.70	+1.34	+1.51
2	Leroy	59	+1.59	+1.70	+1.76	+1.94	+2.10	+1.91	+1.93
3	Leroy	57	+0.50	+0.43	+0.44	+0.41	+0.49	+0.47	+0.44
4	Leroy	36	+2.24	+2.20	+2.14	+1.93	+1.81	+1.76	+1.63
5	Longines	34	−0.37	−0.71	−0.69	−0.99	−0.93	−1.17	−1.30
6	Elgin	77	+6.94	+6.97	+7.09	+7.23	+6.01	+6.86	+6.39
7	Leroy	17	−0.20	+0.07	+0.23	+0.29	+0.36	+0.04	+0.29
8	Elgin	01	−5.04	−5.39	−5.36	−5.54	−5.70	−5.83	−6.04
9	Longines	36	−2.20	−2.37	−2.29	−2.17	−2.21	−2.97	−2.97
10	Longines	60	−2.37	−2.30	−2.10	−1.96	−1.93	−2.01	−1.80
11	Elgin	50	+1.44	+1.39	+1.31	+1.26	+1.53	+2.20	+2.04
12	Longines	34	−0.37	−0.64	−0.80	−1.11	−0.96	−0.71	+0.01
13	Longines	34	−1.20	−1.36	−1.19	−1.13	−0.51	−1.21	−0.57
14	Elgin	49	−0.63	−0.74	−0.69	−0.94	−1.17	−1.07	−1.14

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TABLE III.—ton, D. C., Jan. 19 to July 2, 1917.

omitted.]

			Ordinary temperatures.							
			on not changed.				XII, East.	XII, West.	XII, North.	XII, South.
Temperature..........			1	62.6	65.9	65.6	69.5	71.0	70.3	74.3
Relative humidity....			0	64	61	72	68	65	63	60
	Balance: o=ordinary. v=invar. Hairspring: p=palladium. s=steel.		ay to .	May 14 to 21.	May 21 to 28.	May 28 to June 4.	June 4 to 11.	June 11 to 18.	June 18 to 25.	June 25 to July 2.
Order of merit.	Chronometer or watch.									
				s	s	s	s	s	s	s
1	Negus...	1873	21	+0.01	−0.29	−0.44	−0.23	−0.29	−0.20	0.00
2	Negus...	1980	06	+2.24	+2.24	+2.21	+2.27	+2.37	+2.40	+2.50
3	Negus...	2139	93	+2.07	+2.00	+2.06	+2.13	+2.44	+2.39	+2.30
4	Negus...	2137	91	+0.99	+0.86	+0.94	+0.61	+0.83	+0.90	+0.97
5	Negus...	2054	84	+1.03	+0.84	+0.93	+0.91	+1.07	+1.10	+1.09
6	Lange...	134	24	+0.34	+0.33	+0.31	+0.40	+0.36	+0.56	+0.40
7	Kurtz...	110	30	−1.47	−1.46	−1.09	−0.96	−0.93	−0.89	−0.94
8	Negus...	2148	30	+0.64	+0.60	+0.49	+0.01	−0.49	−0.34	−0.49
9	Negus...	2025	31	+1.39	+1.57	+1.76	+2.16	+2.43	+2.37	+2.67
10	Negus...	1539	33	−0.11	−0.27	−0.26	−0.24	−0.01	−0.01	+0.04
			RIAL.							
....	Leroy...	999	..	......	......	......	......	......	......	......
....	Bliss....	3073	..	......	......	......	......	......	......	......
....	Longines	2059724	..	......	......	......	......	......	......	......
....	Bond...	499	..	......	......	......	......	......	......	......
....	Longines	2059701	..	......	......	......	......	......	......	......
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APPENDIX NO. 2 TO THE ANNUAL REPORT OF THE CHIEF OF THE BUREAU OF NAVIGATION, 1919

ANNUAL REPORT OF THE
NAVAL OBSERVATORY
FOR THE
FISCAL YEAR 1919

WASHINGTON
GOVERNMENT PRINTING OFFICE
1919

APPENDIX No. 2.

REPORT OF SUPERINTENDENT OF NAVAL OBSERVATORY.

Navy Department,
United States Naval Observatory,
Washington, D. C., July 1, 1919.

From: Superintendent, Naval Observatory.
To: Bureau of Navigation.
Subject: Report of the Superintendent, Naval Observatory, for the fiscal year ending June 30, 1919.

Rear Admiral T. B. Howard, United States Navy, retired, continued as superintendent to March 4, 1919, when he was relieved by the present superintendent, Rear Admiral J. A. Hoogewerff, United States Navy.

Up to the date of the armistice, in November, 1918, the personnel of the Naval Observatory was concentrated chiefly on supplying the compasses and compass equipment, navigational instruments, instruments for aviation, nautical almanacs, and time service, not only for a greatly increased Navy, but for the Shipping Board to supply its vessels with navigational equipment.

Fortunately, the services of retired line officers of the Navy who had had duty at the observatory were available; the observatory staff included men accustomed to the use of delicate instruments and qualified to secure and test optical glass. The policy of the Nautical Almanac Office had been to be prepared to duplicate computations furnished during peace by foreign governments by a system of exchange, and the United States Coast and Geodetic Survey could furnish for duty at the observatory Reserve officers who were familiar with practical navigation and surveying.

One of the difficulties encountered was the supply of binoculars and telescopes, because of our previous dependence for optical glass on foreign countries; but the Assistant Secretary of the Navy, Mr. Franklin D. Roosevelt, appealed to the patriotic citizens of the country to lend their glasses to the Navy for the duration of the war at a nominal rental, and 52,000 binoculars and spy-glasses were so loaned, of which 32,000 were suitable, and so enabled our submarine lookouts to be supplied with "Eyes for the Navy." Chronometers, sextants, and other navigational instruments which were the personal property of citizens, and which assisted materially, were also contributed.

The number and capacities of establishments manufacturing nautical instruments, particularly compasses and binnacles, was entirely inadequate to supply the demand, so that establishments not accustomed to such work had to be induced to undertake it under the advice of members of the observatory force who were familiar with the requirements for delicate instruments.

The repair shop at the observatory, which had been established only a few years, proved invaluable in assisting to keep up the supply of instruments.

After the armistice it was necessary to cut down and settle contracts and to take care of overproduction due to the sudden change of conditions. Instruments used during the war and turned in by vessels going out of commission had to be overhauled and the Roosevelt glasses returned to their owners with proper acknowledgment.

By supplying the Shipping Board vessels with part of their navigational outfits the observatory has been enabled to dispose of what would have become a large surplus stock of instruments.

During the year the observations for time were made, the time signals were sent out regularly, a good deal of observational work was done with the various instruments, much reduction of observations was done, the Ephemeris and Nautical Almanac was kept up, and a number of papers were sent to the astronomical journals.

In order to keep up with the demands of navigation for the Navy, including aircraft and submarines, and to make use of the valuable astronomical instruments installed at the Naval Observatory an increased personnel, and with increased pay, particularly in the astronomical, time, and clerical branches, and for the watchmen and firemen is absolutely necessary.

A new boiler to take the place of two which have been in use for 27 years for heating the buildings and which are now worn out beyond repair will have to be provided.

The specific work done by the different departments and divisions is as follows:

DEPARTMENT OF MATERIAL.

Commander J. S. Doddridge, United States Navy, retired, continued as assistant to the superintendent and as head of this department until April 15, 1919, when he was relieved by Capt. G. E. Gelm, United States Navy.

Commander H. E. Smith, Corps of Professors of Mathematics, United States Navy, remained in charge of the supply division and repair shop.

Commander H. Kimmell, United States Navy, retired, continued as inspection and survey officer.

Lieut. Commander W. E. Parker, United States Naval Reserve Force, continued in charge of the compass office until March 21, 1919, when he was placed on inactive duty. Lieut. Commander H. D. McGuire, United States Navy, then took charge of gyro compasses, and Commander J. S. Doddridge, United States Navy, retired, of magnetic compasses.

Commander C. T. Jewell, United States Navy, retired, continued in charge of aviation material during the year.

Lieut. Commander R. S. Patton, United States Naval Reserve Force, continued on duty in charge of the division of nautical instruments and time service. He was placed on the inactive list March 31, 1919. He was relieved by Commander C. S. Graves, United States Navy.

Mr. C. B. Watts continued as assistant with chronometers and time service to March 31, 1919, when he was relieved by Mr. C. C. Wylie.

The following-named officers have been on duty in this department during the year:

Lieut. Commander J. T. Watkins, United States Naval Reserve Force, placed on inactive duty on March 20, 1919; Lieut. F. L. Peacock, United States Naval Reserve Force, placed on inactive duty on March 13, 1919; Lieut. Ray L. Schoppe, United States Naval Reserve Force, placed on inactive duty on March 28, 1919; Lieut. Charles K. Green, United States Naval Reserve Force, placed on inactive duty March 10, 1919; Lieut. J. P. Warburg, United States Naval Reserve Force, placed on inactive duty on December 28, 1918; Ensign L. C. Krusen, United States Naval Reserve Force, transferred to sea duty on August 2, 1918; Ensign Watson L. Johns, United States Naval Reserve Force, placed on inactive duty on January 9, 1919; Ensign Carl L. Oswald, United States Naval Reserve Force, placed on inactive duty on December 11, 1918.

Several Naval Reserve officers on duty at the observatory were from offices of the United States Coast and Geodetic Survey, all of whom by reason of their previous training and zeal rendered valuable service.

INSPECTION SERVICE UNDER THE NAVAL OBSERVATORY.

New York, N. Y., works of the Sperry Gyroscope Co.: Inspector of navigational material, Lieut. Commander H. D. McGuire, United States Navy, relieved by Commander R. C. Lee, United States Navy, on March 4, 1919. Assistant inspectors, Lieut. H. Ernest, United States Navy; Lieut. W. L. Walker, United States Naval Reserve Force; Lieut. H. A. Pinkerton, United States Navy; Lieut. J. L. McGuiness, United States Naval Reserve Force; Ensign L. F. Kepple, United States Navy; and Gunner (T) D. H. Love, United States Navy.

Boston, Mass.: Inspector of navigational material, Lieut. A. J. Ela, United States Naval Reserve Force, was relieved on October 19, 1918, by Lieut. H. E. McComb (junior grade), United States Naval Reserve Force.

San Francisco, Calif.: Inspector of navigational material, Lieut. T. J. Maher, United States Naval Reserve Force, was placed on inactive duty on March 31, 1919. Inspection duties for this district were taken over by the inspection officer, navy yard, Mare Island, Calif. A great deal of material was manufactured in the Philadelphia and Seattle districts. This material was inspected for the Naval Observatory by inspection officers of the navy yards at Philadelphia and Puget Sound. In addition to the commissioned personnel about 30 members of the enlisted personnel were employed in various capacities as subinspectors. This inspection force inspected not only material for the Navy, but also for the United States Shipping Board.

COMPASS OFFICE.

Gyro compasses.—During the year no difficulty was experienced in obtaining equipment for submarines. In July, 1918, a new type of gyro compass was submitted to the bureau for test. This compass is known as the Carrie compass. A board was appointed to conduct a series of tests. As a result of the recommendations of this board, a conditional contract for 100 gyro-compass sets for destroyers was made with the Carrie Gyroscopic Corporation at New York. To date no deliveries have been made on these compasses, although much work has been done, and it appears probable that a satisfactory compass will be obtained. During the fiscal year of 1918 the Arma Engineering Co., of New York, developed a modified type of Anschutz compass. A contract for 20 sets for destroyers was made with this company, conditional upon satisfactory test of a compass to be submitted for this purpose. No deliveries have been made under this contract to date, although considerable progress has been made in developing the compass. The Sperry Gyroscope Co. has had great difficulty in delivering the twin gyro type of compass for destroyers. During the past fiscal year about 20 compasses were delivered. These compasses as at first issued to the service proved unsatisfactory under the conditions encountered. In July, 1918, all deliveries were stopped pending development and modification of the compass as at that time being delivered. This action has resulted in the Sperry Gyroscope Co. making every endeavor to improve this compass, and a successful trial was made on the destroyer *Bush* in March, 1919. Deliveries have again commenced on this type of compass.

The Gyro Compass School was moved from the plant of the Sperry Gyroscope Co. at Brooklyn, N. Y., to the naval operating base at Hampton Roads in September, 1918. This school is very well equipped and should give very good results.

The gyro compass conditions have been greatly improved during the year owing to the appearance of two new firms, who give promise of manufacturing a satisfactory compass. This will relieve the Navy from dependence upon one company and result ultimately in healthy competition.

A new type of floating ballistic for the Mark I compass has been developed and has given good results in rough weather.

Great difficulty was experienced in obtaining ball bearings. Under supervision of the inspector of navigational material at New York successful types of ball bearings were developed in sufficient quantities to meet service and manufacturing requirements.

Magnetic compasses, azimuth circles, and peloruses.—Generally speaking, this equipment has been supplied to the Navy and Shipping Board in sufficient quantities to supply the demands, but it was impossible to supply reserve stock. In September, 1918, a new type of compass card omitting all points and quarter points, except the intercardinal and cardinal points, and marked in degrees from 0°–359°, was adopted. This type of compass is now being issued to the Navy and the Shipping Board. As a result, owing to an agreement with the Shipping Board whereby they took over some of the navigational material, there will be no excess material in this division due to the cessation of the war. In July, 1918, the technical committee of the United States Shipping Board adopted Navy standard equipment for all vessels of 7,000 tons and over. This action will probably lead to the standardization of merchant navigational equipment, a result greatly to be desired.

Since December, 1918, before which time, during the war, it was impracticable, 94 officers have been instructed in compass compensation.

A new type of aviation compass was designed at the observatory, which proved very successful. This compass has been used to some extent by the War and Post Office Departments.

DIVISION OF NAUTICAL INSTRUMENTS AND TIME SERVICE.

Lieut. Commander R. S. Patton, United States Naval Reserve Force, whose services were of great value to the observatory by reason of his Coast Survey training and his ability and energy, continued as head of this division until March 31, 1919, when he was placed on the inactive list in order that he might return to his duties with the Coast and Geodetic Survey.

Commander Carroll S. Graves, United States Navy, reported on March 31, 1919, as head of this division.

Mr. C. B. Watts continued as assistant in chronometers and time service to March 31, 1919, when he was relieved by Mr. C. C. Wylie and transferred to the 6-inch transit circle division. Mr. G. M. Raynsford has been detailed to this department since January 29, 1919.

The continuing increase of the Navy up to the time of the armistice intensified the situation which existed during the preceding year in regard to obtaining nautical instruments, and the observatory was also called upon to fill certain requests of the Army and Shipping Board for them.

American manufacture and grinding of optical glass was accomplished, and adequate supplies of binoculars were being furnished prior to the armistice.

New sources of supply for mirrors and shade glasses were developed, and all necessary demands for sextants were met.

Optical instruments and high-grade timepieces are now being manufactured in this country and the quality is constantly improving.

Time service.—Time signals were sent daily, as usual, at noon and 10 p. m., seventy-fifth meridian time (5 hours and 15 hours, Greenwich mean time). These signals were sent by radio from the station at Radio, Va., as well as by certain other radio stations, and the noon signal was widely distributed by the Western Union and Postal Telegraph Cos. Beginning March 30, 1919, a telegraphic signal for the use of the public has been sent at 4 hours, Greenwich mean time, to correspond to the change of one hour brought about by daylight saving.

The mean daily error of the signals sent from the observatory for the year was 0.038 second. The maximum error was 2.04 seconds. This was due to a jump of two seconds in the clock used temporarily as standard. The jump was discovered at the time of the sending of the signal and the signal was repeated an hour later with an error of 0.03 second. With the exception of this abnormal error, the maximum error was 0.22 second.

Chronometers, torpedo-boat watches, patrol-boat watches and chronometers, clocks, and watches.—A chronometer trial began January 21, 1919, and will finish July 3, 1919. There are in this trial 9 new American chronometers, 39 old chronometers, 18 new torpedo-boat watches, and 4 old torpedo-boat watches.

The following timepieces were received during the year:

Chronometers:	
New, for trial	12
Old, for trial	165
Old, for repair	132
Loaned	19
Torpedo-boat watches:	
New, for trial	35
Old, for trial	48
Old, for repair	35
Patrol-boat watches and chronometers:	
For trial	2,007
For repair	39
Deck clocks, for test	11,686
Aeroplane watches and clocks, for test	4,648
Stop and comparing watches, for test	2,983

The following were issued during the year:

Chronometers:	
Naval	241
Shipping Board	104
Loaned, returned to owners	32
Torpedo-boat watches	111
Patrol-boat watches and chronometers	816

The usual tables showing results of tests of chronometers and torpedo-boat watches under trial will be published in next year's report.

AERONAUTICAL INSTRUMENTS.

This office has continued its function of initiating purchases, inspections, and issues of aviation material under cognizance of the Bureau of Navigation. At the beginning of the year, altimeters and timepieces for aviation were handled by the compass office. These instruments were transferred to the department of aeronautical instruments on January 20, 1919. Aero compasses remain with the compass office.

Ensigns E. B. Buck, C. L. Oswald, W. L. Johns, and H. K. D. Peachy, United States Naval Reserve Force, rendered most efficient services while on duty in this department.

Two officers and five enlisted men were instructed at the observatory in handling navigation material at air stations and were sent to stations where their services were most needed.

Work in connection with aeronautical material, except altimeters, clocks, and compasses, was begun last year and pushed with the idea of furnishing a full equipment for all stations abroad by July 1, 1918. Due to many causes, this program was delayed in some particulars. Outfits of navigational instruments and photographic supplies began going abroad in July, but they were incomplete. Most of the deficiencies were delivered in September or October, and the cessation of hostilities on November 11, 1918, found much material either on the wharves at Philadelphia and Brooklyn awaiting transportation or in the storehouses at Paulliac and Queenstown awaiting issue. Some of this material has been returned and made available for reissue.

Contracts for replacement stores were immediately canceled or adjusted and every effort made to prevent undue expenditure of money. In this the observatory has been fairly successful, and with the exception of the roller chartboards practically all of the equipage and supplies which it was necessary to accept will be useful in the continued maintenance of the service.

During the year two new types of altimeters were delivered, the service having previously depended solely on the product of one company. Altimeters have passed careful tests conducted under direction of the observatory and have been issued to the service. A sample of a fourth type has been ordered.

Under a Navy order placed in the previous fiscal year, there has been manufactured and delivered 50 acceptable pocket recording altigraphs of excellent design and workmanship.

Acceptable altitude barographs have been manufactured, the range having been increased to 25,000 feet.

Aero clocks, wound every minute by electric current, ordered in October, 1918, are being delivered. They are not showing very well on trial and have not yet been put in service.

Several types of course and distance indicators have been manufactured and issued. None are entirely satisfactory, but all are useful and are appreciated by the service.

Bearing plates delivered last year were issued in July and the following months. These are not entirely satisfactory, and the department has been in consultation from time to time with the air pilots, looking toward the design of a more efficient instrument.

Other material for piloting aircraft has been issued from the observatory, but has not been generally used in the service.

Aerial astronomical navigation, which has always occupied a place in the scheme of this department, received an impetus with the preparations for the trans-Atlantic flight of naval seaplanes. The details were worked out in the office of the Chief of Naval Operations and the material for the most part furnished by the observatory. When the experience gained by the officers who made the flight is available for the observatory, further development can be effected.

During July 34 mapping cameras purchased from the Signal Corps of the Army and known as "L-type" were delivered and used. Structural weakness developed in this type camera, but a number are now in use, especially in the southern stations. As these require to be mounted vertically, it was necessary to devise a mount for naval flying boats. One such has been designed at Miami and several mounts have been made and used with fair success. Later, double-pontoon seaplanes of the R-type were assigned to certain stations for photographic work. These carry the L-type of camera on its regular army mount in the center line of the fuselage. However, the L-type has not proved itself entirely satisfactory for naval purposes.

Orders have been placed for 10 film cameras and 10 plate cameras of the type and size (18 by 24 cms.) now approved for Army use.

Hand-held cameras for plates, made by the Folmer & Schwing division of the Eastman Kodak Co. on design suggested by the Naval Observatory, were received in September, and similar cameras for film in December. The plate camera has proved universally popular and successful. It is considered the best camera for oblique work from aircraft yet designed. A number of the same model have been obtained by the Army. The film camera has been successfully used, but has not yet received the favorable comment caused by the Navy hand-held aviation camera for plates.

Practically all the stations in the United States are now completely supplied with photographic outfits.

A very considerable advance in aerography has been made during the year.

The "anemoscope" and "anemobiagraph" have been adopted as standard instruments for measuring and recording, respectively, the direction and force of the wind. Instruments of these types have been issued to all stations equipped for aerography. The anemobiagraph has been found not entirely to replace the cup anemometer, which will be retained for ready reference in obtaining surface wind velocity.

For the upper air, "air-sounding" or pilot ballooning is now the practice at the larger stations. Complete equipment for air sounding has been issued to most of the stations, except as balance for weighing the ascensional list of hydrogen filled balloons. The observatory is awaiting the arrival of models of balloon balances from abroad before standardizing a balance for the air stations.

The observatory has had made two types of "aerographs," instruments intended to be carried by aircraft on aerographic flights, and to record the temperature and humidity at various heights. One type has been delivered but not yet tried.

Barographs, barometers, hygrographs, thermographs, and other instruments of standard types have been issued to the stations.

The observatory has initiated several movements looking to uniformity of method in connection with aerographic work. A form for daily meteorological report has been printed and issued, as well as a monthy inventory of material. Certain of the stations are now cooperating regularly with the United States Weather Bureau.

Aerographic supplies of considerable variety were issued to the base and escort ships used in connection with the trans-Atlantic flight. An aerographic station was also established at St. Johns, Newfoundland, in preparation for the proposed flight of the Navy dirigible, which flight was prevented by the wreck of the craft in a gale.

The observatory has handled requisitions for purchase of feed and supplies for homing pigeons at the air stations.

In August the Navy Department established air stations at Halifax and North Sydney, Canada, which stations were ultimately to be taken over by the Canadian Government. The observatory arranged as complete an outfit of navigation material as possible, so as to make these model air stations. The stations were turned over to the Canadian authorities after the signing of the armistice.

In January the marine expeditionary aviation forces sent to Haiti and San Domingo were given reduced outfits of navigational photographic, and aerographic instruments and supplies.

In February the U. S. S. *Shawmut* was fitted out to serve as "mother ship" for aviation with the fleet.

The Navy Department had a full and well arranged exhibit at the aeronautical exhibition staged in the Madison Square Garden and Sixty-ninth Regiment Armory, New York, in March. The Naval Observatory was represented by a complete exhibit of height, direction, and time instruments.

A smaller exhibit, including a complete set of instruments for piloting aircraft, was held in Philadelphia in April, in connection with the Victory loan.

The observatory has been in consultation with the officers of the Instrument Maintenance School at the Great Lakes Naval Training School and has supplied an outfit of instruments for demonstration and use.

The close of the year finds the observatory with its year's program practically complete. With the exception of the balloon balance already referred to, all the equipage for air stations so far adopted is now at the stations or in store ready for issue.

SUPPLY DEPARTMENT.

Commander H. E. Smith, Corps of Professors of Mathematics, United States Navy, continued as head of the department for the year, aided by Mr. H. G. Hodgkins, assistant in the department of nautical instruments.

A brief summary of the department's work for the year follows.

Value of stock on hand July 1, 1918	$51,027.97	
Instruments, etc., purchased	2,102,887.39	
Instruments received from yards and ships	1,408,547.19	
Instruments issued and expended		$2,266,355.42
Value of stock on hand June 30, 1919		1,296,107.13
	3,562,462.55	3,562,462.55

Number of shipments received (1,936 more than in 1918)	4,451
Number of instruments and parts received (121,192 more than 1918)	201,309
Number of shipments made (2,329 more than in 1918)	6,584
Number of instruments and parts shipped (79,843 more than 1918)	145,666

NAUTICAL INSTRUMENT REPAIR SHOP.

The nautical instrument repair shop has continued the repair of all nautical instruments under the direction of Commander H. E. Smith, Corps of Professors of Mathematics, United States Navy.

One small building was erected during the year for the purpose of testing magnetic compasses, etc.

There are now 11 instrument makers working in the shop, one of whom has been borrowed from the Washington Navy Yard. Efforts have been made throughout the year to fill vacancies in the shop force, but without success owing to the lack of instrument makers on the civil-service eligible list. There are two unfilled positions open at present.

The circular graduating machine contracted for in 1914 was delivered on November 23, 1918. It is being installed and will be in operation by September 1, 1919. The shop will then be able to regraduate both straight and curvilinear scales.

In addition to keeping up with the regular repair work of the Navy, the shop has been able to do some important work for the observatory astronomical department's instruments and has manufactured heeling and semicircular corrector magnets to replace those made by contractors and which failed to pass inspection. Four hundred magnets and 2,592 semicircular magnets (162 sets) were made for this purpose and contractors charged. For this purpose an electric furnace and pyrometer were installed.

During the year the shop foreman has been sent to instruct two firms in making and assembling nautical instruments. Several members of manufacturing firms have come to the observatory for instructions on making liquid compasses, tempering magnet steel, etc.

Extensive experiments as to the inertia, best form, and placement of compass magnets have been made and also experiments as to pivot balance, stability, and best arrangement for maximum directive force. The best results for the latter were obtained with iridium-pointed pivots, which have been adopted.

During the year repairs have been made to 8,406 navigating and surveying instruments, at a cost of $20,539.47. This shows an increase of 80.3 per cent and 34.7 per cent, respectively, over the number of instruments repaired and cost of last year's work.

RETURN OF "ROOSEVELT GLASSES."

In accordance with the promise of the Navy Department to return all binoculars, telescopes, spyglasses, and navigational instruments that were loaned for the period of the war, Lieut. (Junior Grade) A. R. Elmore was detailed to the observatory in December, 1918, to take charge of returning the articles to the original donors.

Lieut. Elmore was relieved by Ensign S. C. Brown, United States Naval Reserve Force, February 12, who took charge of the work on that date.

Twenty-eight thousand of the articles loaned have been returned to the original donors at this time. It may be some time before all articles will be returned, as various ships still holding these articles have not arrived in a port in the United States to forward same to the observatory.

Approximately 800 binoculars, spyglasses, and telescopes remain on hand at the observatory without any marks of identification, the donors having failed to attach proper marks of identification when they forwarded the articles to the observatory.

Thirty-two thousand engraved certificates expressing the appreciation of the Navy Department to those who responded to the call of "eyes for the Navy," have been issued.

INSPECTION.

New instruments came in steadily throughout the year, and the war contracts were not all completed on June 30, 1919. Lieut. R. L. Schoppe, United States Naval Reserve Force, was detached from duty here on March 28 and returned to the United States Coast Survey. Mr. R. B. Potter resigned March 31.

The following new instruments have been inspected and passed:

Aneroid barometers	1,689
Binoculars, night	7,197
Binoculars, prism 6x	6,359

Binoculars, prism 10x	2,594
Captains' reading glasses	1,400
Navigator dividers	2,001
Drafting machines	220
Clinometers	1,466
Sextants	2,351
Stadimeters	1,067
Ship's telescopes	92
Drawing instruments (sets)	161
Spyglasses (H. P.)	203
Spyglasses (M. P.)	305
Spyglasses (L. P.)	1,250
Spyglasses (O. D.)	1,937
Protractors	1,923
Psychrometers	1,300
Psychrometer cases	600
Rulers, parallel	2,281
Mirrors, sextant (sets)	1,268
Mirrors, stadiometer (sets)	421
Mirrors, azimuth circle	670
Wind-velocity indicators	10
T-squares	1,400
Splines and weights	200

In all, 3,136 new and repaired sextants were tested for eccentricity, many more than ever before. Also, all repair work from the shop was inspected and during the last six months great numbers of surveys of returned instruments and material were held.

DEPARTMENT OF NAUTICAL ALMANAC.

This department has continued under the direction of Commander W. S. Eichelberger, Corps of Professors of Mathematics, United States Navy.

The Nautical Almanac Office was organized in 1849, and the first volume of the American Ephemeris and Nautical Almanac, that for the year 1855, was issued in 1852. Since that date the annual volumes have appeared regularly, that for 1921 having been received from the printer on April 21, 1919.

The American Nautical Almanac for 1921 was received from the printer on June 21, 1919.

The number of copies of the annual publications issued for government use, chiefly to the Army, Navy, and Shipping Board, has greatly increased during the past few years and is at present three times that of three years ago. In addition, these publications are sold to the general public by the superintendent of documents.

The complete copy of the American Ephemeris and Nautical Almanac for 1922 has been sent to the printer, and 333 pages are in type.

The following assistants and pieceworkers were employed in preparing for publication the annual volumes of the American Ephemeris and Nautical Almanac. Assistants: James Robertson, William T. Carrigan, Arthur Snow, Arthur Newton, Perez Fisch, George F. Crawley, Clifford S. Lewis, Joseph J. Arnaud, and Frank Langellotti. Pieceworkers: Janet McWilliam, Hannah F. M. Hedrick, Alfred Doolittle, and Isabel M. Lewis.

The investigation of the orbits of Saturn's satellites has been continued. Eighty-two sets of corrections to the elements have been obtained from 16 pairs of satellites, covering 13 oppositions. Equations of condition have been formed for 29 more sets, including 5 additional oppositions.

The uncompleted work of the late Prof. Newcomb on the orbit of the satellite of Neptune has been continued, and at present the differential coefficients for use in correcting the assumed elements have been computed for all the oppositions from 1889 to 1908.

The work of obtaining a new orbit of the seventh satellite of Jupiter has been continued.

The study of the Greenwich Star Catalogues, started several years ago, has been resumed. Some time was devoted to obtaining the difference between day and night observations, and a determination of the refraction from the direct observations over a period of about 30 years is in progress.

The amount of research work carried on during the year has been much less than usual. This is so because of the necessity of employing the higher-grade assistants on certain routine work that could have been done by the three junior assistants had not these positions been vacant. It has been impossible to fill these positions because of the low salaries, $1,200 and $1,000 per annum.

The following assistants and pieceworkers were employed on the various pieces of the above-mentioned work of improving the tables of the planets, moon, and stars. Assistants: William T. Carrigan, Walter M. Hamilton, Arthur Newton, Perez Fisch, and George F. Crawley. Pieceworkers: Janet McWilliam, Hannah F. M. Hedrick, Alfred Doolittle, Henry B. Hedrick, Thomas E. Trott, Louis Lindsey, and Isabel M. Lewis.

An article, "Tables for determining approximately the outline of the region of visibility of an occultation," was published by Mr. Arthur Snow in Popular Astronomy for February, 1919.

DEPARTMENT OF ASTRONOMICAL OBSERVATIONS.

DIVISION OF 6-INCH TRANSIT CIRCLE.

The personnel of this division consisted of Astronomer J. C. Hammond (in charge), Assistant Matt Frederickson to February 19, 1919 (died), Assistant C. C. Wylie to March 31, 1919 (transferred to department of nautical instruments), and Assistant C. B. Watts from April 1, 1919 (transferred from department of nautical instruments). In addition to their regular duties in this division, Mr. Frederickson, Mr. Wylie, and Mr. Watts gave considerable time to the department of nautical instruments and time service in connection with war work.

The number of observations secured during the year is as follows:

Clock stars	303
Time stars	577
Pole stars	33
Refraction stars	15
Day-night stars	73
Inclination stars	20
Sun	19
Mercury	6
Total	1,046

The number of determinations of instrumental constants is as follows:

Collimation	179
Level (spirit)	18
Level (nadir)	182
Marks	179
Nadir	96
Runs	8
Flexure (horizontal)	9
Flexure (vertical)	6
Total	677

The plan of work, begun on May 29, 1916, was completed on August 16, 1918, on which date all observations, with the exception of those for the determination of time, were discontinued temporarily in order that the reduction of the observations made in the last 10 years might be completed and the results published with as little delay as possible. From February, 1909, when the instrument was remounted after repairs, to June 30, 1919, nearly 54,000 observations have been made with this instrument. These observations, which include eight of each 1,260 new standard stars from the lists of Backlund and Hough and over 1,000 of the sun, will be made available as soon as possible for the use of astronomers. The preliminary reductions are already practically completed.

From a discussion of the clock stars observed for a period of seven years, from 1911 to 1918, combined with the results obtained with the personal-equation machine, a good determination of the relative personal equation of the various observers for stars south of the zenith has been made. The adopted corrections for personal equation to be applied to clock corrections determined by the other observers in order to reduce to the system of Hammond are:

	s
Frederickson	+0.010
Tillyer	−0.013
Rines	+0.015
Wylie	−0.005
Aston	0.000

These are of interest because this instrument is equipped with a hand-driven self-registering micrometer. It will be noted that the corrections are small and, what is more important, for those observers whose work extended over a period of several years, there was no evidence of change.

The instrument was reversed three times and the stellar focus adjusted twice during the year.

In August, 1918, the original aluminum heads of the microscope and collimator micrometers were replaced by ones made of white celluloid, which can be more easily read with the rather faint illumination used at night. This work was done by Mr. Rheinbold in the nautical instrument repair shop of the observatory.

CLOCK VAULT.

The temperature in the clock vault was maintained practically constant at 84° F. during the year. Riefler clock No. 60 was used as the standard clock throughout the year and ran extremely well.

Riefler No. 151 was dismounted in January, 1919, to remedy a trouble which it had developed of skipping seconds. The repairs and adjustments of this clock were made by Mr. Rheinbold and Mr. Chapman of the nautical instrument repair shop. It was remounted on March 18 and has run very satisfactorily since that date. Reifler No. 70 also skips seconds occasionally, but otherwise runs well.

The following table gives the mean daily rate of the standard clock as deduced by the time service, together with the maximum variation in the rate for each month.

Month.	Mean daily rate.	Maximum variation.	Month.	Mean daily rate.	Maximum variation.
1918	s	s	1919	s	s
July	−0.28	0.05	January	−0.24	0.04
August	−.29	.04	February	−.25	.03
September	−.26	.08	March	−.26	.03
October	−.27	.05	April	−.26	.04
November	−.25	.04	May	−.28	.02
December	−.24	.04	June	−.29	.04

Total variation in daily rate during the year 0.10 second.

DIVISION OF 9-INCH TRANSIT CIRCLE.

The personnel of this division consisted of Assistant Astronomer Herbert R. Morgan (in charge), Assistant Jesse Pawling, and Assistant Paul Sollenberger.

The 9-inch transit circle was mounted at the Naval Observatory in 1865, and, although repaired at times and in parts reconstructed, it has been used more or less continuously over 50 years for observations of the sun, moon, planets, and brighter stars.

The results of these observations are used for determining more accurately the fundamental constants of astronomy and for improving the tables of motions of the objects in the solar system and of the stars as given in the American Ephemeris and Nautical Almanac—the handbook of all navigators.

Since 1913, by observing a list of some 9,000 standard and intermediary stars on this instrument, the Naval Observatory has been cooperating with the other leading observatories of the world in determining positions of a million of the brighter stars.

The number of observations made during the year is as follows:

Intermediary stars	876	Mercury	46
Standard stars	271	Venus	7
Clock stars (night)	875	Jupiter	16
Clock stars (day)	594	Saturn	16
Azimuth stars	255	Neptune	16
Refraction stars	9		
Sun	88	Total	3,117
Moon	48		

The instrument was reversed three times during the year, and the number of determinations of the instrumental constants is as follows:

Collimation	484	Marks	544
Level	546	Nadir	552

Various other instrumental investigations were carried on. The preliminary reduction sheets are partly reduced to July, 1915, while the preliminary clock corrections and the clock rates are reduced to July, 1918.

To get full value for the instrumental equipment furnished and to enable this Government to do its share of fundamental work, this division should have an increase in the number of observers, which this year was even less than usual, owing to war conditions.

DIVISION OF THE EQUATORIALS.

The personnel of this division consisted of Lieut. Commander Asaph Hall, Corps of Professors of Mathematics, United States Navy (in charge), Assistant Astronomer George H. Peters (in charge of photographic telescope and photoheliograph), Assistant H. E. Burton, and Assistant Ernest Clare Bower.

26-INCH EQUATORIAL.

Observations were made as follows:

Asteroids	4	Comets	46

Of the comet observations 25 were of Wolf's periodic, 18 of Borelly's periodic, and 3 of 1918 d (Schorr).

Comparison stars	3	Satellite VI of Jupiter	4
Double stars	11	Satellite of Neptune	26
Occultations	27		

Determinations of the following were also made:

Value of one revolution of the micrometer screw from arcs	6
Value of one revolution of the micrometer screw by transits	2
Instrumental constants	1
Coincidences	19
Parallels	103
Personal equation	15

On 28 nights during the period July 21–December 12, 1918, Prof. Hall and R. B. Potter, of the division of inspection of nautical instruments, searched for and examined faint objects near Uranus. In this connection it was decided to try a dew cap, and a temporary one was provided for the telescope.

Two Jupiter asteroids, (659) Nestor and (588) Achilles, were searched for on account of their theoretical interest. Three nights were spent in looking for Nestor, but it was not found. Achilles was easily found, due to the accuracy of the ephemeris, by Julie M. Vinter Hansen, of Copenhagen University Observatory, and four observations were obtained. There were few nights favorable for observation of such faint objects owing to the interference of moonlight and haze.

The first observations made in the United States of the new comet 1918 d (Schorr), magnitude about 15 when observed, were obtained with the 26-inch equatorial of the Naval Observatory. All three comets listed were followed until they became too faint to be satisfactorily observed.

Occultations of stars by the moon, furnishing one of the best methods of correcting the tables of the moon's motion, are regularly observed in the United States only at the Naval Observatory as far as known.

The sixth satellite of Jupiter on account of being a faint object is generally included in the observing program for the 26-inch, and the satellite of Neptune is interesting on account of the curious motion of the plane of its orbit.

The double-star observations were made by request of Dr. A. D. Risteen, of Hartford, Conn., who is making a theoretical investigation of the motions of the system 70 Ophiuchi, and had asked for observations later than those that could be found in existing double-star catalogues.

The Repsold micrometer, made in 1913, was used for all observations and the value of a revolution of the screw—

$$R=20''.8347+0''.000022[T^\circ(F.)-50^\circ]+0''.0535[0^{in}.810\text{-focal scale}]$$

was obtained from measures of the difference in declination between the well known stars 5 and 12 in Perseus, Krueger's numbers, i. e., B. D. 56° No. 498 and B. D. 56° No. 543, combined with measures of the difference in declination of stars 1 and 2 in Pleiades and 14 and 18 in Pleiades, Yale numbers, the last two pairs being selected from the star list in Transactions of the Astronomical Observatory of Yale University, Vol. I, p. 351.

A series of observations of an equatorial star by transits was begun as an independent method of finding the value of a revolution of the micrometer screw, and two nights' observations gave $R=20''.8354$ for a mean temperature of 69° F. and focal scale at $0^{in}.818$.

12-INCH EQUATORIAL.

With this instrument 27 occultations were observed.

VISITORS. 12-INCH EQUATORIAL.

The public, which had been excluded from the observatory as a war measure upon the opening of hostilities, has been admitted on the regular Thursday evenings, by card, to the 12-inch equatorial since February 6, 1919, and Mr. Peters, in addition to exhibiting objects with the telescope, has given talks on astronomical topics, while the observations are carried on. The number of visitors received during this period, which has been unusually cloudy, is 471, including schools admitted on special nights. The demand for cards of admission always exceeds the number of people who can be accommodated.

Assistant Wm. A. Conrad has continued to use the 12-inch for volunteer work and has obtained the following asteroid observations up to November 14, 1918, in addition to 45 published in Astronomical Journal No. 731, of which 25 were listed in last year's annual report:

(15) Eunomia	1
(39) Laetitia	11
(64) Angelina	2
(68) Leto	3
(78) Diana	1
(101) Helena	13
(192) Nausikaa	12
(198) Ampella	7
(385) Ilmatar	2
(554) Peraga	7
(712) Boliviana	1
Total	60

The observing program for the 26-inch equatorial has been cut down to allow more time for computations and solutions for correction of the elements of the satellites of Saturn from the series of observations covering the period 1909–1916.

To date the solutions both for 11 and 12 unknown quantities have been made for the following pairs:

Tethys-Dione (1909–10), (1910–11), 1911–12), (1912–13); Tethys-Rhea (1909–10), (1910–11), 1911–12), (1912–13); Dione-Rhea (1909–10), (1910–11), (1911–12); Rhea-Titan (1909–10), (1910–11), (1911–12).

In this work this division has been assisted by the computing division. The places and differential coefficients upon which these solutions were based were computed and checked by the Nautical Almanac department.

All members of the equatorial division took part in the extra work performed by the division of nautical instruments and time service during the war.

Contributions to the Astronomical Journal were made as follows:

	A. J. No.
1. Second elements and ephemeris of 1917, W15, by Bower and Wylie	739
2. Occultations by the moon, 1917, Oct. 21; 1918, June 11, by Hall, Burton, and Bower	740
3. Observations of Nova Aquilae No. 3, 1918, June 9–11, by Hall, with notes; 1918, June 12–15, by Hall and Burton	740
4. Elements and ephemeris of 1915, YJ, by Bower	749
5. Note on apparent place of asteroids and comets, by Bower	750
6. Observations of minor planets, 1918, Feb. 28–Nov. 14, by Conrad	753
7. Observations of minor planets, 1912, Mar. 10; 1916, May 31, by Watts, Bower, and Webster, unpublished.	
8. Occultations by the moon, 1918, July 20; 1919, June 23, by Hall, Burton, and Bower, unpublished.	
9. Ephemeris of (886) Washingtonia, by Bower, unpublished.	

Of the foregoing, 1, 4, 5, and 6 were volunteer work.

The following contribution appeared in Popular Astronomy for May, 1919: "The 26-inch equatorial of the U. S. Naval Observatory," by Asaph Hall.

PHOTOGRAPHIC TELESCOPE.

The absence of Mr. Peters from the observatory during considerable periods on war service, in connection with optical supplies, curtailed the usual number of observations with the photographic telescope.

The following minor planets were observed photographically:

(30) Urania	2	(415) Palatia	2
(100) Hekate	2	(429) Lotis	2
(125) Liberatrix	2	(487) Venetia	2
(163) Erigone	2	(540) Rosamunde	2
(198) Ampella	1	(625) Xenia	2
(276) Adelheid	2	(886) Washingtonia	3
(402) Chloe	2		

Photographs were also made of 10 asteroid fields, where the sought-for planets were not found. Eight fields for special objects were also photographed.

A list of asteroids observed to January 1, 1919, has been sent to the Astronomical Journal.

The following articles were published by Mr. Peters: The photographic telescope of the U. S. Naval Obesrvatory, Popular Astronomy, June, 1919; Observations of asteroids made with the photographic telescope of the Naval Observatory, August 10, 1917, to December 15, 1917, Astronomical Journal No. 752.

PHOTOHELIOGRAPH.

Photographs of the sun have been taken on 139 days. Solar spots and groups have been observed on each of these days. An increase of activity has lately been noted indicating the approach to the period of secondary maximum in the solar cycle.

MIRRORS AND SHADE GLASSES FOR SEXTANTS.

Mr. Peters was engaged in expert optical work during a considerable part of the year to secure an output of sextant shade glasses and sextant mirrors by American firms for the Navy.

This material previous to the war had been obtained principally from European sources. The supply of skilled labor for this work was very limited. Instruction in methods of refinement for quantity production had to be furnished. Mr. Peters' experience enabled the Navy to place an optical expert in the field to secure the needed production, and he prepared a paper entitled "Hints on the Care and Use of Optical Instruments at Sea."

DIVISION OF PHOTOGRAPHIC ZENITH TUBE AND ALT-AZIMUTH.

This division has been in charge of Commander F. B. Littell, Corps of Professors of Mathematics, United States Navy. Assistant Astronomer G. A. Hill has assisted in the observational work. Assistant W. A. Conrad has assisted in the observations and reductions, but about one-third of his time has been devoted to work outside of this division, due in part to congestion of work in the observatory caused by the war.

PHOTOGRAPHIC ZENITH TUBE.

The preliminary reductions indicate that this instrument is continuing to give results of the same high quality for the variation of latitude work that it did in its original installation at Gaithersburg, Md. These results will be available for any general discussion of the motion of the pole and to furnish corrections to the meridian observations of declinations made at the Naval Observatory. The observing list and program has been the same as for the preceding years since this instrument was removed to this site in 1915. The number of star observations secured during the year was 1,544. The reduction of these observations is kept nearly up to date, and it is expected that they will soon be in form for publication.

ALT-AZIMUTH.

The same observer is employed to operate the photographic zenith tube and to observe with the alt-azimuth, as the program for the former instrument necessarily leaves many time intervals of considerable length. These intervals are employed in determining the declinations of the fundamental stars by observations with the alt-azimuth, which is used as a quickly reversible meridian circle, each star being observed in both clamps at the same culmination. The stars on the program are those of the Liste Générale Provisoire d'Etoiles Fondamentales contained in the Supplement a la Connaissance des Temps pour l'An 1914, culminating within 75° of the zenith. However, the work of the photographic zenith tube prevents observing the complete list. The telescope micrometer and the microscope micrometer are provided with reversing prisms. The alidade is provided with three levels.

The number of observations of stars secured with this instrument was 646 to November, when star observations were discontinued in order that division error work might be carried on. Since that time the corrections for division error have been determined as far as the degree lines.

DIVISION OF THE PRIME VERTICAL TRANSIT INSTRUMENT.

This division has been in charge of Assistant Astronomer George A. Hill.

During the past year observing has been suspended in order to give time for reduction and discussion of the 19-year series of observations made with the instrument.

The discussion of the four groups of stars observed, so as to bring their declinations into a complete system, was continued in the present fiscal year and has been finished.

The corrections derived from this discussion have been applied to the latitudes secured each night, in each group, for the purpose of forming final definitive latitudes. Those latitudes were then plotted and the curve of Variation of Latitude drawn through them.

In the early part of 1904 the latitude of the Naval Observatory was less than its mean latitude. It then began to increase in value and reached a maximum about January 1, 1905, when it began to fall again, and reached a minimum about April, 1906. Another maximum was reached in the middle of January, 1907, followed by a smaller minimum in late July, 1907.

The maximum in the first part of 1908 was also a small one, but the minimum that took place in late November, 1908, was slightly larger in phase than the previous one. From this time until the end of 1912 each maximum and minimum showed a larger phase than those that had preceded them.

In the list of stars that were observed with the prime vertical transit the declinations of 21 of them are contained in Prof. Newcomb's Catalogue of Fundamental Stars, and 77 of them in the General Catalogue of Prof. Boss.

The Newcomb stars, based upon 2,465 observations, indicate as the latitude of the clock house

$$+38^\circ\ 55'\ 14.031''.$$

The Boss stars, based upon 3,313 observations, give for the same reference point

$$+38^\circ\ 55'\ 14.428''.$$

Another interesting discussion that has been made during the year has been a comparison of the declinations of a large number of stars, observed with the instrument, and their places as published in the Lund Zone Catalogue, Yarnall's Catalogue, observed at Washington, and Lalande's Catalogue. The epochs of these catalogues are 1875, 1860, and 1800, respectively.

A large number of these stars were observed at the old Naval Observatory with the old prime vertical transit, between 1842 and 1855, while many in the Lalande Catalogue were observed prior to 1800. A comparison with these observations indicates a proper motion in declination of more than 10″ a century for quite a number of these faint stars.

In making the comparison with the catalogues mentioned those stars for which a proper motion in declination has been published were not included.

Another discussion that has consumed some time has been that of the inequality of the pivots of the prime vertical transit for the entire period of the series of observations. Some very interesting results have been secured in that discussion.

The material to be incorporated in the prime vertical volume is now in shape to proceed with writing the manuscript of the text, which has been in progress for the past two months, and a large number of pages have been prepared.

COMPUTING DIVISION.

This division has been in charge of the executive committee. The personnel consisted of Assistant Eleanor A. Lamson, Miscellaneous Computer Wm. Katz (until Aug. 1, 1918; resigned); Miscellaneous Computer G. M. Raynsford (until Mar. 18, 1919), assistant from that date (detailed to time service department since Jan. 29, 1919); Miscellaneous Computers A. C. Richmond, Mrs. I. R. Burton, Marjorie Chace (until Aug. 22, 1918; resigned), Florence P. Allen (from July 10 until Sept. 14, 1918; resigned), Elsa S. Fowle (until Aug. 22, 1918; resigned), R. B. Gurley (until July 16, 1918; resigned), W. H. Chambers (from July 22 to Sept. 7, 1918; resigned), J. D. Wise (from Sept. 13, 1918), R. D. Gustin (from June 21, 1919); Pieceworkers Mrs. C. M. Ferner (until Aug. 1, 1918, and from Apr. 29, 1919), Mrs. S. S. Bower (until Aug. 1, 1918), Mrs. C. S. Lewis (until Aug. 1, 1918), Mrs. C. M. Conrad (from Oct. 31, 1918), Florence P. Allen (from May 3, 1919).

REDUCTION OF THE 9-INCH TRANSIT CIRCLE WORK 1913–1916.

This work which comprises the right ascension and declination reduction of the observations is being continued.

REDUCTION OF THE 6-INCH TRANSIT CIRCLE WORK 1911–1918.

This work which comprises the right ascension and declination reduction of the observations is well advanced.

REDUCTION OF EQUATORIAL OBSERVATIONS.

Seven sets of observation equations from observations of pairs of Saturn's satellites at three oppositions have been solved to determine corrections to the elements of their orbits.

PUBLICATION OF VOLUME IX, PART I.

The completion of this work, on which the printing had been started as announced in the last annual report, has been prevented by the pressure of war work at the Government Printing Office.

This part of Volume IX contains the discussion of the observations made with the 9-inch transit circle 1903–1911, the final results of the individual observations, and the star catalogue resulting from these observations.

LIBRARY.

Mr. W. D. Horigan continued as librarian throughout the year.

	Volumes.	Pamphlets.	Total.
Contents of library July 1, 1918	29,657	5,788	35,445
Accessions:			
By purchase	253	4	257
Through exchange	69	63	132
Total	29,979	5,855	35,834

The following publications were printed:

	Copies.
Annual Report of the Naval Observatory, 1918	2,500
American Ephemeris and Nautical Almanac, 1919	500
American Ephemeris and Nautical Almanac, 1921	1,300
American Nautical Almanac, 1919	4,346
American Nautical Almanac, 1920	1,542
American Nautical Almanac, 1921	3,000

There were distributed 7,728 publications of the institution, including 4,527 copies of the American Nautical Almanac for 1919 to the Government service.

BUILDINGS, GROUNDS, AND ROADS.

Commander T. G. Dewey, United States Navy, retired, has had charge of buildings, grounds, and roads during the past year, and though somewhat handicapped by the inability of securing laborers the buildings, roads, and grounds were kept in good condition.

In October the contractor finished and turned over to the superintendent the nonmagnetic building authorized by the Navy Department for compass work.

A new return tank for the boiler house was installed, and it will be necessary during the summer of 1920 to replace the two old E. L. Dent boilers with a new one. These boilers have been in constant use for 27 years. They were retubed 15 years ago, but the shells are in such bad condition that the inspector of boilers does not consider them worth repairing.

J. A. Hoogewerff,
Rear Admiral, United States Navy.

Approved:
Thos. Washington,
Chief of Bureau of Navigation.

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APPENDIX NO. 2 TO THE ANNUAL REPORT OF THE
CHIEF OF THE BUREAU OF NAVIGATION, 1920

ANNUAL REPORT OF THE
NAVAL OBSERVATORY

FOR THE

FISCAL YEAR 1920

WASHINGTON
GOVERNMENT PRINTING OFFICE
1920

APPENDIX NO. 2.

REPORT OF SUPERINTENDENT OF NAVAL OBSERVATORY.

NAVY DEPARTMENT,
UNITED STATES NAVAL OBSERVATORY,
Washington, D. C., July 1, 1922.

From: Superintendent, Naval Observatory.
To: Bureau of Navigation.
Subject: Report of the Superintendent, Naval Observatory, for the fiscal year ending June 30, 1922.

Capt. W. D. MacDougall, United States Navy, reported and assumed the duties of superintendent on August 1, 1921, relieving Capt. G. E. Gelm, United States Navy, who had been acting superintendent since the detachment of Rear Admiral J. A. Hoogewerff, United States Navy, on June 8, 1921.

The astronomical council has been composed of the superintendent, the assistant superintendent, and the following astronomers, viz, Capt. W. S. Eichelberger (mathematics), United States Navy; Capt. F. B. Littell (mathematics), United States Navy; Commander A. Hall (mathematics), United States Navy; Astronomer J. C. Hammond, Astronomer G. A. Hill, and Assistant Astronomer H. R. Morgan.

The executive committee has been composed of the following astronomers, viz, Capt. F. B. Littell (mathematics), United States Navy; Commander A. Hall (mathematics), United States Navy; and Astronomer J. C. Hammond.

The Naval Observatory, under naval administration as the material branch of the Bureau of Navigation, has continued to supply the Navy and the country with its essential products, viz:

Time, the time signals being transmitted through the naval radio stations to navigators at sea for finding their position. The signals, sent by both radio and telegraph, establish standard time throughout the country. They have been used as far away as Australia.

The Nautical Almanac, for navigators, surveyors, and for industrial and scientific use.

Astronomical data, by making continuous observations for position of the heavenly bodies. (On this sort of data all other astronomical work, including time and the Nautical Almanac, is founded.)

Navigation instruments, their supply and upkeep for naval vessels and aircraft.

The nautical-instrument repair shop has continued to prove its value to the Navy in the economical repair of nautical instruments for ships and stations.

The regular program of astronomical work has been followed in accord with the plans laid out by the superintendent and the astronomical council as required by the organization of the Observatory.

As it was desirable for the United States Naval Observatory to be represented at the Conference of the International Astronomical Union held at Rome in May, 1922, and as there were no funds available for such representation, Capt. F. B. Littell, Corps of Professors of Mathematics, United States Navy, was authorized to proceed at his own expense as a delegate from the Naval Observatory and from the National Research Council. Time signals and the determination of longitude thereby were important subjects of discussion at the conference and are vitally connected with the work of the Naval Observatory.

The specific industries of the different departments and divisions are described under appropriate headings. The lists of personnel are included for purposes of record and to give some slight recognition of valuable scientific services ably and faithfully rendered by the technical staff at small cost to the Government.

DEPARTMENT OF MATERIAL.

Capt. G. E. Gelm, United States Navy, continued as assistant to the superintendent and as head of the department until detached on May 29, 1922. He also performed the duties of supply officer during this period. Commander W. F. Newton, United States Navy, took over these duties on May 29, 1922.

Lieut. Commander J. G. Stevens, United States Navy, was temporarily in charge of the magnetic-compass office from July 1, 1921, to October 7, 1921, and November 25, 1921, to December 19, 1921. Commander Paul P. Blackburn, United States Navy, was in charge of the office from October 7, 1921, to November 25, 1921. Commander W. F. Newton, United States Navy, was in charge of the magnetic-compass office from December 19, 1921, to June 30, 1922.

Commander H. Kimmell, United States Navy (retired), continued as inspection officer.

Lieut. Commander J. G. Stevens, United States Navy, continued in charge of the division of nautical instruments and time service.

Commander C. T. Jewell, United States Navy (retired), continued in charge of aeronautical instruments and aviation material until February 28, 1922, upon which date he was relieved from active duty, and the duties were taken over by Commander W. F. Newton, United States Navy, and consolidated in the magnetic-compass office.

Commander L. P. Davis, United States Navy, continued in charge of the gyro-compass division until September 26, 1921, when the duties were taken over by Lieut. Commander P. L. Carroll, United States Navy, who had been assistant from June 11, 1921.

Lieut. T. P. Clark, United States Navy, continued as assistant in the gyro-compass office.

INSPECTION SERVICE UNDER NAVAL OBSERVATORY.

Commander W. R. White, United States Navy, relieved Commander J. C. Fremont, United States Navy, as inspector of navigational material at New York City on July 11, 1921.

Commander G. K. Calhoun, Corps of Professors of Mathematics, United States Navy, was assigned to duty as assistant to inspector of navigational material for special work in gyro-compass design on September 21, 1921.

Ensign H. E. Stevens, United States Navy, relieved Lieut. H. Ernest, United States Navy, as assistant inspector of navigational material on September 11, 1921.

MAGNETIC COMPASS OFFICE.

The routine review of compass reports from vessels has been executed.

Upon the recommendation of destroyer force commanders, binnacles and pelorus stands have been allowed to remain on decommissioned destroyers. Instructions were given for the careful storage of the compasses removed. They should be ready for immediate use upon the recommissioning of the destroyers or Eagle boats.

As destroyers received their gyro-compass equipments, they were directed to turn into store the illuminated dial peloruses supplied with their original navigational outfit, using as a substitute the gyro repeaters fitted with graduated bezels.

A new type of bracket for the peloruses of submarines has been designed so that either a dummy pelorus or a gyro repeater can be fitted in this bracket.

A transparent-card magnetic compass with projecting optical system has been tested on the *S-50* and favorably reported upon by the board of inspection and survey and by the submarine officers. This type of magnetic compass is to be installed on the "S" and later submarines.

The apparatus of the compass school has been kept available for any officers ordered to take the compass course. Only one reported. It is understood that, due to the shortage of line officers in the Navy, none were available for compass instruction.

GYRO-COMPASS OFFICE.

Performance.—In general the gyro-compass equipments of battleships and cruisers have given excellent service except in heavy weather; of submarines, satisfactory except during rolling; and of destroyers, unsatisfactory. The types of gyro compasses which have given this performance are, for battleships and cruisers, Sperry Mark I, II, and V, and for destroyers, the Sperry Mark III twin wheel. Three Sperry Mark IV twin-wheel type in use on auxiliaries have not been satisfactory. Experimental installations of the Sperry Mark VI and the Arma Mark I gyro compasses in active service in the destroyer force have been successful.

Developments.—During the period of report the developments worthy of mention are; the qualifying of competitors in the gyro-compass field in the Arma Engineering Co. of Brooklyn and the Ford Instrument Co. of New York; the successful trials of gyro-compass equipments for destroyer use in the Sperry Mark VI and the Arma Mark I; the improved operation of the Sperry single-wheel type of compass by the incorporation of the mercury ballistic into its design (particularly the added reliability during rolling in heavy weather); and the beginning of definite experimental work for the purpose of increasing the value of the gyro compass as a fire-control instrument.

Plans.—Based on the experience of the period of report, it is planned to procure under existing contracts and install on active destroyers 20 Arma Mark I equipments and 24 Sperry Mark VI equipments. Of the latter, 16 are in replacement of unsatisfactory and worn out Sperry Mark III equipments; all others are original installations for destroyers which have never been supplied. If the performance of this apparatus continues to justify the present confidence in it, other contracts involving 20 or 30 equipments will be made.

The modification of 20 Sperry Mark I and II master compasses to the mercury ballistic type is now going on at the works of the Sperry Co. It is proposed when these are ready to distribute them to battleships and submarines for replacement of the masters installed, these to be shipped to the Norfolk yard, where in the future alterations will be made. There will thus be started a program of modification of all compasses of this type in service, which will proceed at a rate dependent upon availability and funds.

The destroyer *Osborne* is now being equipped with the following compasses: Sperry Mark V, Sperry Mark V with ballistic releasing device for improving fire-control qualities, Sperry Mark VI, Arma Mark I, and Ford Mark I. It is proposed to compare these compasses in ordinary service and under various conditions of roll caused by the gyro stabilizer also installed on the *Osborne*, and also to conduct a special series of tests to determine behavior under the disturbing forces caused by turning, accelerating, and backing of vessel. The purpose of trials is not only to determine which type of compass best holds the meridian under disturbing conditions, but to obtain accurate data which will help the manufacturers to improve design in overcoming the effects of disturbing factors.

Policy.—The matters discussed above are concerned only with the gyro compass as an instrument. To produce improvement in design, reduce cost of upkeep, and obtain better operating, there are other matters concerning policy which fall within the duties of the Naval Observatory. There appears below a statement of policy which is the aim of the gyro-compass office. Certain parts of this policy have already been approved by the Bureau of Navigation and put into effect; other parts will be presented to the bureau as recommendations in the future. It is believed that the policy outlined is for better operation at reduced cost.

(A) Increase the general knowledge of the gyro compass throughout the service.

(*a*) Detail one postgraduate officer each year for the subject of electrical engineering with special concentration on gyroscopics.

(*b*) Detail all postgraduate officers for six weeks during their courses in the works of gyro-compass manufacturers.

(*c*) Require a practical knowledge of the gyro compass as a qualification for electrical gunner.

(*d*) Detail electrical gunners not now qualified in gyro-compass work to four months' course as opportunity allows.

(*e*) Instruct all enlisted men at electrical schools in gyro-compass care and operation.

(B) Develop to a greater extent gyro-repair facilities in the fleet.

(*a*) Establish on every repair ship and tender a thoroughly equipped gyro-repair shop and detail expert officer in charge.

(*b*) Establish at operating and submarine bases a thoroughly equipped gyro repair shop and detail expert officer in charge.

(C) Centralize the shore activities on each coast in the operating bases at Hampton Roads and San Diego.

(*a*) Establish schools for officers and enlisted men at these bases.

(*b*) Assemble all spare and surplus equipment at these bases under expert supervision and accomplish upkeep and training of students by using them in its care.

(*c*) Maintain only at these bases stocks of spare parts for issue to ships and shore stations.

(*d*) Maintain central depots for spare master compasses tested and ready for issue to service in replacement of compasses showing faulty operation, the latter to be returned to these bases for overhaul.

(D) Eliminate the officer specially detailed to navy yards as gyrocompass officer.

(*a*) Make present gyro shops part of electrical shops and abolish as separate shops.

(*b*) Place such gyro work as is required squarely up to electrical gunner assistant shop superintendents.

(*c*) Send gyro expert to yard if occasion arises for need.

(*d*) Do not repair master compasses at yards; obtain spare masters from bases and return defective masters to bases for overhaul.

(*e*) Maintain present repair equipment for use of ship's force and for installation work.

DIVISION OF NAUTICAL INSTRUMENTS AND TIME SERVICE.

The Naval Observatory in its nautical instrument repair shop is now making repairs to nautical instruments and navigation equipment of vessels and stations of the Atlantic coast, with the few exceptions of heavy or cumbersome articles, such as sounding machines, binnacles, etc., for which transportation would be expensive.

Under direction of this division, nautical instruments and navigation equipment have been supplied to newly commissioned vessels and to the several vessels received during the year from the Shipping Board and from the Army. Material from obsolete naval vessels has been removed and turned into store prior to sale of such vessels. Material from decommissioned destroyers has been turned into store in "used material account" at Philadelphia, San Diego, and Mare Island.

Several new instruments and devices of various kinds and for various purposes in connection with navigation of vessels have been presented for examination, trial, etc.

Mr. Paul Sollenberger and Mr. G. C. Whittaker continued as assistants in chronometer and time service throughout the year and Mr. A. C. Richmond as an assistant from July 1 to September 23, 1921, and from June 29 to June 30, 1922.

Time service.—Time signals were sent by the Naval Observatory daily at noon and 10 p. m. seventy-fifth meridian time (5 hours and 15 hours Greenwich mean time). These signals were broadcasted from the naval radio stations at Annapolis, Arlington, and Key West, and the noon signals were widely distributed by the Western Union and Postal Telegraph Cos. The average error of the time signals sent during the year was 0.038 second and the maximum error 0.60 second.

At the request of Mr. G. F. Dodwell, Government astronomer, Adelaide Observatory, South Australia, the Naval Observatory sent a series of special time signals from the Annapolis Radio Station at 2.55 to 3 p. m. daily from June 20 to July 12, 1921, for use in determining longitude and establishing boundaries in Australia.

Considerable experimental work has been carried on in the time service in connection with the determination of lag of the transmitting sets of stations sending time signals and with a view to bettering the reception and recording of radio signals.

With a view to determining the possible existence of a diurnal variation of standard high-grade clocks, daily comparisons were made between the standard Riefler clocks of the Naval Observatory and the Riefler clock of the Bureau of Standards at 10 a. m., 4 p. m., and 10 p. m. during the period from October 3, 1921, to May 15, 1922. The reductions not having been completed, results of the experiment can not be announced at the present time.

Chronometers, torpedo-boat watches, patrol-boat chronometers, patrol-boat watches, clocks and watches.—Two chronometer trials were held during the year, the first from August 3, 1921, to January 9, 1922, and the second from January 19 to June 26, 1922. The accompanying tables show data for chronometers and torpedo-boat watches that passed the above trials. (Tables VII, VIII, IX, X, and XI.)

The following timepieces were received during the year:

Chronometers:	
New, for trial	23
Old, for trial	150
Old, for repairs	147
Torpedo-boat watches:	
New, for trial	44
Old, for trial	69
Old, for repairs	64
Patrol-boat watches and chronometers:	
New, for trial	30
Old, for trial	144
Old, for repairs	126
Stop and comparing watches, old for test	194
Stop and comparing watches, new for test	28
Deck, boat, aeroplane, and wall clocks for test	363

All timepieces, except chronometers, torpedo-boat watches, patrol-boat watches, and patrol-boat chronometers, were turned over to the supply officer for stock after test. The following were issued during the year by this division:

Chronometers	163
Torpedo-boat watches	31
Patrol-boat watches and chronometers	106

AERONAUTICAL, NAVIGATIONAL, AND AEROLOGICAL INSTRUMENTS.

The Bureau of Aeronautics was, by General Order No. 65, established on August 10, 1921, thus discontinuing the aviation section of the Bureau of Navigation as such. The order that established the new bureau put under the cognizance of the Bureau of Navigation all aircraft compasses and instruments for aerial navigation, ground instruments used in connection with air navigation, and the aerological instruments at naval air stations and on board aircraft carriers and tenders.

The Naval Observatory has continued handling the Bureau of Navigation correspondence in regard to the design, procurement, and issue of aeronautical, navigational, and aerological instruments for aircraft, aircraft carriers, and air stations. A plan for handling Bureau of Navigation affairs which require the expenditure of funds chargeable to appropriation for aviation was formulated by representatives of the bureaus concerned and approved.

Developments of aeronautical, navigational, and aerological instruments follow:

Two new types of aero compasses were tested in March. The Briggs-Heyl earth inductance compass was tried out in a *DH-4* plane at Anacostia and was later given a thorough test at the Naval Observatory shop and compass house. The Sperry gyro compass was tried out in an *F-5-L* plane and later tested at the naval air station at Anacostia. Unfortunately neither one of these compasses is yet properly developed for use in heavier-than-air machines. The Sperry gyro compass could be satisfactorily used in large airships of the ZR type.

The aerial sextant as designed by Lieutenant Commander Byrd is considered the best artificial horizon sextant that has been tried out. Five Navy Standard sextants fitted with the Fischer artificial horizon attachment have just been received from Keuffel & Esser Co., and it is believed that these instruments will be an improvement.

The British low-reading altimeter as manufactured by Short & Mason, of London, has proved successful and is the best low-reading altimeter that we now have for issue. A temperature-compensated high-reading altimeter was developed by the Bureau of Standards. Further experiments are necessary.

Altitude azimuth instruments for observing pilot balloons have been delivered to the Observatory from three sources: Keuffel & Esser Co., E. S. Ritchie & Sons, and the Washington Navy Yard. These three types of instruments are different, though intended for the same purpose. They are being tested by the aircraft tender *Wright*.

Pilot balloons, 6 and 9 inch and 7½ inch, as manufactured by the United States and Faultless Rubber Co., respectively, have passed excellent tests and are now being issued to the service.

A plotting board designed by Keuffel & Esser Co. for plotting the positions of these pilot balloons in their ascensions is being tested at Anacostia.

A luminous-ground wind indicator, manufactured by the Air Transport Equipment Co., of Long Island, is being tested at Anacostia. This indicator is in use at McCook Field and at Hazelhurst Field.

The air stations and the U. S. S. *Wright*, *Aroostook*, and *Langley* have been fitted out with complete sets of aerological instruments. All 24-hour drum aerological instruments have been changed to 7-day ones.

A chapter on aerial navigation for the new book on navigation that is to be used by midshipmen was compiled by the officer in charge of the aeronautic desk at the Naval Observatory.

SUPPLY DEPARTMENT.

(Mr. H. G. Hodgkins, assisting supply officer.)

Value of stock on hand, July 1, 1921	$2,016,740.71	
Value of instruments, etc., purchased	39,426.63	
Value of instruments, etc., received from yards and ships	136,452.09	
Value of instruments issued and expended		$504,019.47
Value of stock on hand June 30, 1922		1,688,599.96
	2,192,619.43	2,192,619.43

Number of shipments received	1,556
Number of instruments and parts received	16,305
Number of shipments made	1,897
Number of instruments and parts shipped	13,782

INSPECTION.

(Mr. Jacob Rheinbold, foreman of nautical instrument repair shop, assisting.)

Owing to supply on hand, not many new instruments were purchased. More than the normal quantity were returned from ships and stations for survey, the shop making repairs for stock in addition to those for ships.

The following new instruments and material have been inspected and passed during the year:

Anemometers (complete)	20
Buzzers	5
Adjustable curved rulers	100
Azimuth circle mirrors	400
Batterburg course indicators	20
Compass cards	50
Invar tapes	9
Mariners practical star finders	25
Mercurial barometer tubes	60
Parallel rulers	924
Sextants, high grade	100
Splines and weights (sets)	25
Steel tapes	12

DEPARTMENT OF NAUTICAL ALMANAC.

This department has continued under the direction of Capt. W. S. Eichelberger, Corps of Professors of Mathematics, United States Navy.

Mr. Charles L. Rush was appointed assistant, at $1,200 per annum, on December 1, 1921.

Miss Elsie V. Keith was appointed assistant, at $1,200 per annum, on April 1, 1922.

Mr. Wm. T. Carrigan, assistant, after 21 years' connection with the office, died on January 20, 1922.

The American Ephemeris and Nautical Almanac for 1924 was received from the printer on January 9, 1922.

The American Nautical Almanac for 1924 was received from the printer on June 30, 1922.

Four hundred and sixty-five pages of the American Ephemeris and Nautical Almanac for 1925 are in type.

The investigation of the orbits of Saturn's satellites has been continued. One hundred and eight sets of corrections to the elements have been obtained from 18 pairs of satellites, covering 15 oppositions. Equations of condition have been formed for 48 more sets, including six additional oppositions.

The determination of the orbit of Neptune's satellite, based on 1,006 observations covering the period from 1889 to 1908, has been completed and the results have been prepared for publication.

The work of obtaining a new orbit of the fifth satellite of Jupiter has been continued.

An intercomparison of four modern catalogues has been made in order to obtain corrections to the star places of the American Ephemeris based on modern observations. These catalogues are Cape Fundamental Catalogue, 1900 (1905–1911); Second Cape Fundamental Catalogue, 1900 (1912–1916); Catalogue of 4,526 Stars from Observations with the 9-inch Transit Circle (1903–1911). Publications of the United States Naval Observatory, second series, Volume IX, Part I; and Catalogue of Stars from Observations with the 6-inch Transit Circle of the United States Naval Observatory (1911–1918), not yet published.

The following assistants and pieceworkers were employed on the work of the office during the year: Assistants, James Robertson, William T. Carrigan, Arthur Snow, Walter M. Hamilton, Arthur Newton, Perez Fisher, George F. Crawley, Clifford S. Lewis, Morris Liferock, Catharine de M. Lewis, Charles L. Rush, and Elsie V. Keith; pieceworkers, Janet McWilliam, Hannah F. M. Hedrick, Thomas E. Trott, and Isabel M. Lewis.

DEPARTMENT OF ASTRONOMICAL OBSERVATIONS.

DIVISION OF 6-INCH TRANSIT CIRCLE.

The personnel of this division consisted of Astronomer J. C. Hammond (in charge) and Assistant C. B. Watts.

Observations for time were made regularly throughout the year, the average interval between the separate determinations being 3½ days. The instrument was reversed six times.

The number of observations of time and azimuth stars, made on 109 nights, is—

Time stars	624
Azimuth stars	15
Total	639

The number of determinations of instrumental constants is—

Collimation	114
Nadir level	114
Zenith level	17
Marks	114
Total	359

The observations, made during the period 1909–1918, are completely reduced and are being prepared for publication. The equinox corrections to the standard catalogues of Newcomb and Boss, resulting from about 1,000 observations of the sun during the period 1911 to 1918, are, respectively, $-0^{s}.053$ and $-0^{s}.047$.

Since May, 1922, the observations for time have been reduced with values of the level constant determined in the zenith by means of the vertical collimator. This is an attempt to increase the accuracy of the time determinations by eliminating as far as possible systematic errors due to flexure.

The divided circles of the instrument were cleaned on June 26 by Mr. Rheinbold, of the nautical instrument repair shop.

CLOCK VAULT.

The temperature in the clock vault was maintained practically constant at 84° F. during the year.

Riefler clock No. 60 was used as the standard clock until August 12, Riefler No. 151 from August 12 until December 22, Riefler No. 70 from December 22 until February 28, and Riefler No. 60 from February 28 until the end of the year.

Riefler No. 70 was cleaned and adjusted in November, Riefler No. 60 in January, and Riefler No. 151 in March.

The work was done by Mr. Chapman of the nautical instrument repair shop.

The following table gives the mean daily rates of the three Riefler clocks in the vault and the maximum variations in the rates for each month:

Month.	No. 60.		No. 70.		No. 151.	
	Mean daily rate.	Maximum variation.	Mean daily rate.	Maximum variation.	Mean daily rate.	Maximum variation.
1921.						
July	+0^{s}.12	0^{s}.01	+0^{s}.13	0^{s}.05	+.0^{s}.03	0^{s}.08
August	....	0.21	+0.19	0.03	−0.01	0.06
September	+0.10	0.03	+0.18	0.06	−0.07	0.04
October	+0.10	0.04	+0.18	0.10	−0.10	0.02
November	+0.10	0.01	....	....	−0.09	0.05
December	+0.10	0.02	+0.01	0.05	−0.13	0.02
1922.						
January	....	....	−0.01	0.04	−0.12	0.03
February	−0.12	0.07	−0.04	0.04	−0.12	0.06
March	−0.19	0.05	....	....	−0.16	0.02
April	−0.21	0.02	....	....	....	....
May	−0.23	0.02	−0.05	0.06	−0.21	0.06
June	−0.24	0.03	−0.11	0.07	−0.22	0.02

Riefler No. 60 ran very irregularly in the first part of August.

Riefler No. 70 was unsealed in March and again in April to adjust the winding contact.

DIVISION OF 9-INCH TRANSIT CIRCLE.

The personnel of this division consisted of Assistant Astronomer Herbert R. Morgan (in charge), Assistant Astronomer H. E. Burton, Assistant Jesse Pawling, and Assistant G. M. Raynsford.

The observations of the intermediary and standard stars, begun August 1, 1913, have been continued, together with observations of the sun, moon, planets, and day clock stars; and the number of observations made during the year is as follows:

Intermediary stars	2,991	Venus	7
Standard stars	945	Mars	14
Clock stars (day)	480	Jupiter	15
Clock stars (night)	1,487	Saturn	15
Azimuth stars	282	Uranus	15
Refraction stars	46	Neptune	16
Sun	85		
Moon	87	Total	6,528
Mercury	43		

And the total number of observations made since the beginning of the work is 55,296. The instrument was reversed four times during the year, and the number of determinations of instrumental constants is—

Collimation	685	Marks	711
Level	712	Nadir	713

Besides other instrumental investigations carried on, the pivots were measured for irregularities, determinations of flexure were made, and various measures were taken on the personal equation machine.

The preliminary clock corrections and the clock rates are reduced to November, 1920. Except for application of clock corrections, the first three years' work (1913–1916) has been reduced to mean place. Considerable reductions have been made for the later years. An examination was made of the variation in the clock correction during the night for the period 1913–1920.

DIVISION OF THE EQUATORIALS.

The personnel of this division consisted of Commander Asaph Hall, Corps of Professors of Mathematics, United States Navy (in charge), Assistant Astronomer George H. Peters (in charge of photographic telescope and photoheliograph), and Assistant Ernest Clare Bower.

26-INCH EQUATORIAL.

Observations were made as follows:

Comparison stars	5	Satellites of Mars	12
Occultations	21	Satellite VI of Jupiter	1
Eclipses, Jupiter's Satellites I and II	9	Satellites of Uranus	22
Comet 1922b (Skjellerup)	6	Satellite of Neptune	6

Determinations of the following were also made:

Value of micrometer revolution by transits of equatorial stars	5
Coincidences	17
Parallels	102

Poor seeing on an unusual number of nights during the year was detrimental to the work.

The screw of the Repsold micrometer of the 26-inch equatorial was re-examined by Professor Hall and Mr. Bower. The periodic and progressive errors were found to agree substantially with those previously determined. Both are negligible. The eccentricity of the position circle of this micrometer was determined by Mr. Bower; also, this micrometer was removed from the instrument and cleaned by Mr. Rheinbold, foreman of the nautical instrument shop.

The trucks and guide wheels of the 26-inch dome were repaired and adjusted under the direction of the acting superintendent of the Observatory, Captain Gelm, assisted by Mr. Bower.

12-INCH EQUATORIAL.

With this instrument were observed 16 occultations and 5 eclipses of Jupiter's Satellites I and II.

The Observatory was open to visitors by card for viewing the heavens through this instrument and for inspection of the time service on 66 nights. of which 12 were cloudy. There were 2,844 visitors, including those received on special nights assigned to schools.

Most of the observations taken during the period 1908–1922 have been copied and arranged for printing.

The observation equations for Dione-Rhea, satellites of Saturn, for the opposition 1914–15 were solved by the computing division. From the measures taken with the 26-inch equatorial during the period 1909–1916 it appears that a positive correction is to be added to the assumed values of the semiaxes major of the satellites of Saturn, thus increasing the value of the planet's mass.

PHOTOGRAPHIC TELESCOPE.

Photographs were made of 75 asteroid fields on 55 nights, most of these in the zones selected for this work. The zones vary in declination with the seasons, and are as follows:

+4° to +8°, March, April, September, and October;
+0° to +4°, May to August, inclusive;
+12° to +16°, November to February, inclusive.

Photographs are usually taken near the time of opposition of the asteroids.

Recently 82 of these photographic observations were turned over to the computing division for reduction, and the computations for 57 of these have been completed. All the plates taken for the asteroid positions were measured by Mr. Peters, and the comparison stars were selected and reduced by him.

About 50 more asteroid plates remain to be measured and reduced.

On November 21, 1921, an asteroid of the 10.5 magnitude, which could not be identified, was found upon a plate exposed for Eros (433). A series of photographic observations for position, covering an arc of 65 days, was made of this object.

The elements of the orbit as computed by Miss Lamson, and also by Messrs. Bower and Newton, show that the asteroid is probably new. It has been tentatively named Anacostia.

A number of copies on glass from eclipse negatives have been made for illustrations in the eclipse report soon to be published.

An illustrated article by Mr. Peters, entitled "The New Electric Driving Clock of the Photographic Telescope of the Naval Observatory," was published in Popular Astronomy, Vol. XXX, No. 2, for February, 1922. To test the clock and to furnish an illustration for the article, a long-exposure photograph was taken of the great star cluster in Perseus.

PHOTOHELIOGRAPH.

The sun was photographed on 215 days. Solar spots or groups were observed on 149 of the photographs. The minimum phase of the sun-spot cycle is now approaching.

There has been a notable decrease for several months past in the number of days when spots existed on the visible surface of the sun. The faculae also have recently diminished, both in numbers and in area.

The solar condition as observed with the photoheliograph have been reported immediately to the Western Union Telegraph Co. This is in connection with investigations of wire and cable disturbances on their lines, which become acute at times and interrupt traffic.

The data thus furnished are charted by the telegraph company, together with their own observations of line disturbances and auroras, and copies of the charts are forwarded to the Naval Observatory for discussion. It is hoped that the more intense magnetic or electrical storms originating in the sun and affecting terrestrial conditions may be predicted eventually with some degree of certainty from solar observations.

In connection with investigations carried on by the United States Naval Radio Research Laboratory, Bureau of Engineering, the photographs of the sun taken at the Naval Observatory are also examined with reference to a possible relation between solar disturbances and wireless statics.

DIVISION OF PHOTOGRAPHIC ZENITH TUBE AND ALT-AZIMUTH.

This division has been in charge of Capt. F. B. Littell, Corps of Professors of Mathematics, United States Navy. Assistant J. D. Wise has assisted in the observations and reductions throughout the year and Miscellaneous Computer J. E. Willis has assisted in the observations from March 6.

PHOTOGRAPHIC ZENITH TUBE.

The results for the year 1920 have been published in the Astronomical Journal and the results for 1921 are nearly ready for publication. The aberration constant deduced from the 1921 observations is 20.″47, agreeing well with the results of the five preceding years during which this instrument has been in service here.

The number of observations secured during the year was 1,828.

ALT-AZIMUTH.

A few observations of stars were made with this instrument and also some experimental observations of the sun. A new arrangement for installing the thermometers is being made, providing for the application of the principle of the Assmann aspiration thermometer.

DIVISION OF THE PRIME VERTICAL TRANSIT INSTRUMENT.

This division has been in charge of Astronomer George A. Hill.

The plan of work for the instrument approved in the previous year has been continued. Its purpose, as stated in the last annual report, is to secure modern positions in declination of a list of zenith stars, with an additional purpose of obtaining their proper motion in that coordinate, should such be revealed.

A large number of these stars were observed with the prime vertical transit at the old observatory and are published in Professor Yarnell's catalogue. As a rule the epoch of observation for these stars in that catalogue is about 1855. This will give the very satisfactory interval of 70 years between dates of observing.

A number of the stars in the list observed during the past fiscal year indicate proper motions of 10″ or more per century. These stars have not been announced in star catalogues as having proper motions in declination.

During the year 523 observations have been made. The chronograph times of transit have been entered in the observing books of all these stars and their first reduction made to October 7, 1921.

The material for the prime vertical volume has been under discussion during the past year and is now practically completed. This includes the tables with a few exceptions.

The series of observations of the declination of α Lyrae has revealed what is probably the most pronounced so-called daylight effect that has been found, and it is clearly shown to vary according to the hour in daylight when the star was observed. All the observed declinations were secured by one observer and with the same instrument.

All the declinations were corrected for an erroneous proper motion, for the variation of latitude, and to the new aberration constant. The complete series was then formed into 37 groups. Each of these groups contain all the declinations secured for the whole period in any 10 day interval, commencing with January 1. The number of declinations included in each of these groups averages about 50.

An examination of this material indicated that a parallax for the star could not be obtained by combining both the night and day observations. Therefore a solution was made using only those declinations that were obtained when the sun was below the horizon. The value of the parallax obtained is 0.121″.

In No. 24 of the publications of the Groningen Laboratory Prof. J. C. Kapteyn has published as the parallax of α Lyrae the value obtained by Flint at Madison Observatory, +0.10″, and that by Elkins, of Yale College Observatory, +0.082″. These are relative parallaxes and Professor Kapteyn reduces them to an absolute parallax by applying a correction so they become +0.108″ and +0.089″, respectively. The parallax of the star obtained with the Naval Observatory instrument is an absolute parallax.

After this parallax had been secured it was applied to each of these 37 groups, as an additional term in the reduction to mean place. The mean of all the night observations was then formed and from it was subtracted each of these 37 groups.

If these declinations are plotted, as they will be in the forthcoming volume, it will be seen that those observed between 11.30 a. m., and 12.30 p. m. are 0.35″ smaller than the mean of the declinations observed during the night.

From 12.30 p. m. toward sunset, or from 11.30 a. m. toward sunrise, the hourly declinations increase in amount and reach two maxima, one near 6 p. m. and the other about 7 a. m.

No direct connection has been found between this variation and that of the azimuth of the sun.

COMPUTING DIVISION.

This division has been under direction of the executive committee and supervised by Miss Lamson. The personnel consisted of Assistant Eleanor A. Lamson; miscellaneous computers, Mrs. I. R. Burton, Mrs. L. T. Zahn, J. E. Willis, and A. C. Richmond (from June 6, 1922); pieceworkers, Mrs. C. M. Ferner (until April 12, 1922; transferred to Hydrographic Office), Mrs. C. B. Watts (until April 12, 1922; transferred to Hydrographic Office), A. C. Richmond (from September 23, 1921, to June 6, 1922), F. E. Swindells (resigned November 12, 1921), Mrs. C. M. Conrad; and Florence P. Allen. The following work has been accomplished:

For the 9-inch transit circle.—This comprised the preliminary reduction in right ascension and declination of the star observations on the general reduction sheets for the period September, 1916, to July, 1917. The reduction of the clock stars on the sheets for the determination of the clock correction for the period September 30, 1918, to November 25, 1920, has also been completed. Over 5,000 star observations have been reduced to mean place.

For the 6-inch transit circle.—This work consisted largely of the application of the final corrections to the star places and obtaining the mean positions which are to be used in forming the catalogue.

For the equatorials.—One set of normal equations of Saturn's satellites, the pair Dione-Rhea (1914–15), has been solved. Preliminary elements of a new asteroid discovered by Mr. Peters on his photographic plates in November, 1921, have been computed and, together with a finding ephemeris for the next opposition, have been sent to the Astronomical Journal for publication. The plate measures of a series of asteroid observations extending over the period October, 1920, to March, 1922, have been reduced to right ascension and declination for the epoch 1925.0.

Reports of total solar eclipses.—The printer's copy of the reports on the work of the two eclipse expeditions sent out by the Naval Observatory, the former to Spain and Africa, in 1905, and the latter to Baker, Oreg., in 1918, has been practically completed, except photographs.

For the prime vertical instrument.—The checking of the introduction, the preparation of the tables, etc., of this work for publication has been continued.

For the photographic zenith tube and alt-azimuth.—Over 2,300 stars were reduced to mean place for the alt-azimuth work and about 500 for the photographic zenith tube.

LIBRARY.

Mr. W. D. Horigan continued as librarian throughout the year.

	Volumes.	Pamphlets.	Total.
Contents of the library July 1, 1921	30,608	5,930	36,538
Accessions:			
By purchase	232	0	232
Through exchange	275	80	355
Total	31,115	6,010	37,125

There were distributed 4,218 publications of the institution, including 756 copies of the American Ephemeris and Nautical Almanac for 1922 and 2,384 copies of the American Nautical Almanac for 1922.

CONTRIBUTIONS TO CURRENT ASTRONOMICAL LITERATURE.

The following publications have appeared in the Astronomical Journal during the year:

1. Observations of Comet 1920 *b* (Taylor), December 20, 1920, to February 14, 1921, by Bower (No. 789).
2. Occultations by the moon, July 2, 1920 to April 21, 1921, by Hall and Bower (No. 790).

3. Observations of the satellites of Uranus, August 8 to November 13, 1920, by Hall (No. 793).
4. Observations of 1921 J B Barcelona, February 12 to March 11, 1921, by Peters and Bower (No. 794).
5. Asteroid (Reinmuth) April 1, to April 11, 1921, by Bower (No. 794).
6. Comet Pons-Winnecke, May 9 to June 14, 1921, by Bower (No. 794).
7. Comet 1921 *c* (Dubiago), May 25 to May 31, 1921, by Bower (No. 794).
8. Observations of the satellite of Neptune, December 14, 1920, to April 11, 1921, by Hall (No. 795).
9. Observations of the satellites of Saturn, October 20 to December 21, 1909, by Hall and Eppes (No. 795).
10. Observations of eclipses of Jupiter's Satellites I and II, January 16 to May 8, 1921, by Hall and Bower (No. 795).
11. Observations of the satellites of Saturn, September 7, 1910, to January 16, 1911, by Hall (No. 798).
12. Observations of Comet 1921 *a* (Reid), March 22 to May 31, 1921, by Bower (No. 802).
13. Observations of the satellites of Uranus, August 24 to November 25, 1921, by Hall (No. 802).
14. Observations of the satellites of Saturn, September 6, 1911, to January 27, 1912, by Hall and Burton (No. 803).
15. On Aberration and Parallax in Orbit Computation, by E. C. Bower (No. 796).
16. Elements and Finding Ephemeris of (1921 W 19), by E. A. Lamson (No. 807).
17. On the Daily Variation in Clock Corrections, by W. S. Eichelberger and H. R. Morgan (No. 795).
18. Variation of Latitude Observations at Washington 1920.0–1921.0 by F. B. Littell (No. 789).

The following is a partial list of further contributions:

1. The Mass of Neptune, by W. S. Eichelberger and A. Newton. (Paper read at 26th Meeting of Amer. Astron. Society; published in Pop. Astron., November, 1921.)
2. A New Orbit of Neptune's Satellite, by W. S. Eichelberger and A. Newton. (Paper read at 27th Meeting of Amer. Astron. Society; published in Pop. Astron., February, 1922.)
3. Daylight Observations with a Transit Circle, by J. C. Hammond. (Paper read at 27th Meeting of Amer. Astron. Society; published in Pop. Astron., March, 1922.)
4. Daily Variation in Clock Corrections and Rates, by J. C. Hammond. (Paper read at 27th Meeting of Amer. Astron. Society.)
5. Preliminary Discussion of the Corrections to the Constant of Nutation from Day and Night Observations in Declination of *α* Lyrae, by E. A. Lamson and G. A. Hill. (Paper read at 27th Meeting of Amer. Astron. Society; published in Pop. Astron., March, 1922.)
6. The Position of Neptune's Equator, by A. Newton. (Paper read at 27th Meeting of Amer. Astron. Society; published in Pop. Astron., March, 1922.)
7. The New Electric Driving Clock of the Photographic Telescope of the U. S. Naval Observatory, by G. H. Peters. (Paper read at 26th Meeting of Amer. Astron. Society; abstract published in Pop. Astron., December, 1921.)
8. The New Electric Driving Clock of the Photographic Telescope of the U. S. Naval Observatory, by G. H. Peters. (Published in Pop. Astron., February, 1922.)
9. The Node of Solar Eclipses and Related Phenomena, by Arthur Snow. (Published in Pop. Astron., January, 1922.)
10. Chas. Henry Davis, 2d, R. Adm. (ret.), U. S. N. (deceased December 27, 1921) (former superintendent of U. S. Naval Observatory). (Published in Pop. Astron., March, 1922, and in Science, February 24, 1922.)

BUILDINGS, GROUNDS, AND ROADS.

The buildings, roads, and grounds were maintained in good condition.

A contract in the amount of $1,000 was let to Alexander St. John & Son, of Washington, D. C., for necessary repairs to the copper roof of the main building, and the work was completed January 17, 1922.

In January a new boiler was installed in the observers' sleeping quarters for heating the quarters to replace the old boiler in that building worn out in use, which was sent to the Washington Navy Yard for junk.

W. D. MacDougall,
Captain, United States Navy.

Approved:
Thos. Washington,
Chief of Bureau.

TABLE I.—*Data of trial of old chronometers at United States Naval*

[The signs are astronomical, +losing; −gaining. Data

									Mean daily rates.			
									Special temperatures (orientation not changed).			
Temperature .... degrees F..									90	85	70	55
Relative humidity by sling psychrometer .... per cent..									23	25	34	45
Order of merit.	Balance: o=ordinary. v=invar. Hairspring: p=palladium s=steel.			Balance, hairspring.	Trial number.	Point of compensation.			Feb. 5 to 12.	Feb. 13 to 20.	Feb. 21 to 28.	Mar. 1 to 8.
	Chronometer.		Kind.			Temperature.	Rate.	Temperature constant.				
						°	s	s	s	s	s	s
1	Bliss	2957	M. T. S.	o. p.	5.31	77.2	+0.82	+0.00098	+1.03	+1.07	+0.83	+1.20
2	Negus	2262	M. T. S.	o. p.	7.18	75.6	+1.26	+0.00142	+1.47	+1.51	+1.40	+1.80
3	Knoblich	[1] 2405	M. T. S.	....	7.45	35.6	−3.48	+0.00053	−1.77	−2.23	−2.86	−3.21
4	Negus	2166	M. T. S.	o. p.	7.63	32.5	−3.10	+0.00044	−1.80	−1.90	−2.43	−2.90
5	Adams	4613	M. T. S.	o. s.	9.00	69.0	−0.23	+0.00160	+1.01	+0.36	−0.16	−0.07
6	Nardin	605	M. T. S.	v. s.	9.92	50.0	+1.21	+0.00027	+1.49	+1.43	+1.46	+1.10
7	Bliss	3054	M. T. S.	v. s.	10.75	97.2	−0.69	+0.00072	−0.23	−0.39	−0.30	+0.36
8	.....do	3204	M. T. S.	o. p.	11.48	43.1	−0.31	−0.00038	−0.99	−1.06	−0.66	−0.39
9	Negus	2247	M. T. S.	o. p.	11.82	44.7	−2.52	+0.00024	−1.74	−1.93	−2.20	−2.41
10	Fosler	[2] 259	M. T. S.	....	13.80	42.0	+0.44	−0.00009	[+2.60]	+[2.20]	+1.31	+0.41
11	Negus	2177	M. T. S.	o. p.	14.46	52.1	−4.01	+0.00058	−2.59	−3.07	−3.87	−4.01
12	.....do	1298	M. T. S.	o. s.	15.46	69.6	−1.66	+0.00287	−0.67	−0.97	−1.87	−1.21
13	Bliss	3043	M. T. S.	o. s.	15.90	42.5	+0.06	−0.00007	−0.01	+0.07	−0.14	−0.20
14	Jensen	101	M. T. S.	v. s.	16.42	48.3	−0.21	+0.00091	+1.21	+0.94	+0.19	−0.23
15	Negus	[2] 1293	M. T. S.	o. s.	16.47	69.0	+0.26	+0.00236	[+1.69]	+1.07	+0.46	+0.79
16	.....do	1850	M. T. S.	o. s.	16.50	67.6	−0.68	+0.00327	+0.61	+0.16	−0.70	−0.07
17	Bliss	3155	M. T. S.	o. p.	17.48	27.8	+0.39	−0.00036	−0.73	−0.74	−0.41	+0.10
18	Kullberg	8429	M. T. S.	....	19.33	76.0	+0.17	+0.00111	0.00	−0.11	+0.13	+0.36
19	Negus	[1] 2155	M. T. S.	o. p.	21.24	11.5	−0.46	−0.00022	−1.99	−1.84	−1.41	−1.07
20	.....do	1470	S. B. C.	o. s.	22.00	53.7	−0.30	+0.00098	+1.27	+0.64	−0.33	−0.26
21	Bliss	3191	M. T. S.	o. p.	22.18	47.5	−1.27	+0.00011	−0.81	−1.01	−1.29	−1.27
22	Knoblich	2305	M. T. S.	....	22.35	60.1	−0.77	+0.00216	+1.30	+0.87	−0.30	−0.49
23	Negus	[1] 2141	M. T. S.	o. s.	23.09	75.9	+0.45	+0.00042	+1.36	−0.06	+0.84	+0.90
24	.....do	1890	S. B. C.	o. s.	24.65	69.1	−2.65	+0.00222	−1.61	−2.11	−2.34	−1.99
25	.....do	1518	S. B. C.	o. s.	25.67	63.5	−2.44	+0.00338	−0.06	−0.91	−2.03	−2.13
26	.....do	1784	M. T. S.	o. s.	25.94	176.1	+4.91	−0.00036	+1.56	+1.64	+0.76	−0.30
27	Bliss	3095	M. T. S.	v. s.	26.40	64.9	−3.72	+0.00084	−3.26	−3.39	−3.81	−3.57
28	.....do	3166	M. T. S.	o. p.	29.07	88.5	−0.25	+0.00091	+0.89	−0.21	0.00	+0.63
29	Negus	2069	M. T. S.	o. s.	30.69	37.0	−2.90	+0.00067	−1.17	−1.81	−2.04	−3.06
30	Bliss	3143	M. T. S.	o. p.	31.04	63.6	−1.62	+0.00240	−0.76	−0.63	−1.94	−1.80
31	.....do	3162	M. T. S.	o. p.	31.25	73.6	−2.10	+0.00187	−1.84	−2.21	−2.46	−1.71
32	Bond	457	M.T.B.C.	o. s.	33.35	78.5	−1.37	+0.00396	−0.51	−0.90	−1.13	+1.09
33	Johannsen	4745	M. T. S.	o. p.	34.58	∞	......	....	−0.81	−0.49	−1.40	−2.07

[1] Chronometer withdrawn before completion of trial.

[2] Chronometer not started at beginning of trial. Quantities in brackets based on following rates.

M. T. S.=mean time standard chronometer.

M. T. B. C.=mean time break circuit chronometer.

S. B. C.=siderial break circuit chronometer.

Observatory, Washington, D. C., February 5, 1920, to July 9, 1920.

of chronometers with trial numbers greater than 35 omitted.]

Mean daily rates.															
Special temperatures (orientation not changed).						Ordinary temperatures (orientation changed).									
50	50	55	70	85	90	67.4	67.6	67.4	69.1	69.5	69.8	72.9	73.0	73.6	75.1
49	52	53	40	38	32	51	61	58	69	67	69	70	71	72	63
Mar. 9 to 16.	Mar. 16 to 23.	Mar. 25 to Apr. 1.	Apr. 3 to 10.	Apr. 12 to 19.	Apr. 21 to 28.	Apr. 30 to May 7.	May 7 to 14.	May 14 to 21.	May 21 to 28.	May 28 to June 4.	June 4 to 11.	June 11 to 18.	June 18 to 25.	June 25 to July 2.	July 2 to 9.
s.	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*
+1.37	+1.59	+1.41	+0.91	+0.69	+0.70	+1.00	+1.09	+1.21	+1.13	+1.08	+1.07	+0.90	+0.94	+0.94	+0.83
+1.97	+2.14	+1.91	+1.19	+1.24	+1.04	+1.49	+1.51	+1.53	+1.49	+1.47	+1.47	+1.44	+1.40	+1.26	+1.16
−3.03	−3.29	−3.36	−2.84	−2.13	−1.50	−2.94	−2.80	−2.74	−2.97	−2.70	−2.73	−2.77	−2.56	−2.63	......
−2.99	−2.79	−2.86	−2.53	−1.86	−1.66	−2.69	−2.71	−2.80	−2.87	−2.57	−2.40	−2.33	−2.17	−2.26	−2.20
+0.46	+0.66	+0.23	−0.30	0.00	+0.73	−0.20	−0.34	−0.07	−0.21	−0.07	−0.31	−0.24	−0.56	−0.37	−0.34
+1.31	+1.64	+1.34	+1.19	+1.64	+1.81	+1.63	+1.84	+2.00	+2.04	+2.21	+2.33	+2.34	+2.26	+2.57	+2.47
+0.60	+0.84	+0.79	−0.01	−0.76	−0.70	+0.21	+0.11	+0.39	+0.21	+0.39	+0.27	−0.04	+0.16	−0.10	−0.13
−0.21	−0.09	−0.33	−0.49	−0.89	−1.00	−1.04	−0.94	−0.64	−0.64	−0.31	−0.37	−0.34	−0.33	−0.46	−0.74
−2.47	−2.50	−2.57	−2.53	−2.31	−2.21	−2.57	−2.54	−2.50	−2.57	−2.46	−2.50	−1.86	−1.96	−1.91	−1.84
+0.34	+0.11	+0.30	+1.30	+2.20	+2.60	+1.13	+1.44	+1.53	+0.74	+1.33	+1.40	+1.47	+1.49	+1.74	+1.86
−3.59	−3.56	−4.01	−3.79	−3.71	−3.34	−4.07	−3.93	−4.11	−4.41	−4.29	−4.53	−4.63	−4.17	−4.21	−4.23
−0.47	−0.36	−0.89	−1.46	−0.99	−0.31	−1.16	−1.46	−1.39	−1.49	−1.68	−1.67	−1.86	−1.81	−1.77	−1.63
−1.00	−0.57	+0.30	+0.16	−0.19	−0.54	+0.41	+0.10	−0.27	+0.23	+0.34	+0.19	+0.46	+0.29	+0.14	−0.13
−0.41	−0.24	−0.11	+0.24	+1.11	+0.76	+0.01	+0.24	+0.50	+0.67	+0.77	+0.81	+0.91	+0.43	+0.81	+1.37
+1.00	+1.16	+0.66	+0.06	+0.64	+1.49	+1.29	+0.54	+0.47	+0.31	+0.49	+0.51	+0.37	+0.51	+0.63	+0.50
+0.27	+0.17	−0.24	−0.61	+0.46	+1.20	−0.59	−0.97	−0.83	−0.83	−0.54	−0.74	−0.43	−0.60	−0.47	−0.40
+0.23	+0.51	+0.16	−0.07	−0.80	−0.91	+0.11	+0.69	+0.73	+0.84	+0.87	+0.99	+1.13	+1.19	+1.00	+0.47
+0.93	+1.07	+0.96	+0.29	+0.63	+0.90	+0.66	+0.91	+1.17	+1.10	+1.36	+1.16	+1.31	+1.36	+1.59	+1.46
−0.96	−0.96	−0.70	−1.04	−1.47	−1.60	−1.00	−0.90	−0.77	−0.57	−0.37	−0.37	−0.19	−0.10	−0.11	......
−0.14	+0.81	−0.33	+0.26	+0.69	+1.29	−0.10	−0.20	−0.71	−0.89	−0.49	−0.60	−0.57	−0.71	−0.69	−0.69
−1.14	−0.93	−1.26	−1.13	−1.21	−1.13	−1.10	−1.17	−1.07	−0.99	−0.70	−0.70	−0.23	+0.03	0.00	−0.07
−0.43	−0.04	−0.96	−0.81	+0.27	+1.13	−0.96	−0.99	−1.13	−1.00	−0.64	−0.80	−0.23	−0.26	−0.27	−0.30
+0.83	+0.84	+0.36	+0.07	+1.03	+1.47	+0.76	+0.83	+0.91	+0.93	+0.91	+0.87	+1.00	+0.89	+0.99	......
−1.64	−1.77	−2.43	−2.96	−2.07	−1.39	−2.53	−2.77	−2.83	−2.57	−2.74	−2.71	−2.86	−2.61	−2.06	−3.63
−1.86	−1.84	−2.26	−2.56	−0.86	+0.10	−2.10	−2.54	−2.61	−2.76	−2.69	−2.63	−2.79	−2.49	−2.51	−1.89
−0.23	−0.39	−0.31	+1.06	+2.27	+2.29	+0.93	+0.94	+0.84	+1.51	+1.73	+1.49	+2.01	+2.13	+2.00	+2.07
−3.63	−3.86	−3.71	−3.60	−3.37	−3.13	−4.17	−3.73	−3.47	−3.24	−3.16	−2.83	−2.81	−2.64	−2.67	−2.50
+0.97	+1.09	+0.91	+0.13	−0.27	−0.29	−0.33	−0.49	−0.69	−0.37	+0.51	−0.11	−0.29	+0.07	+0.39	+0.01
−3.50	−2.29	−2.30	−2.30	−0.90	−1.99	−1.57	−2.47	−2.11	−2.04	−1.99	−2.16	−1.57	−1.77	−1.90	−2.11
−1.47	−1.09	−1.07	−1.10	−0.41	−0.43	−1.04	−1.14	−0.80	−0.81	−0.94	−0.30	−0.60	−0.07	−0.53	−0.19
−1.29	−1.33	−1.20	−1.70	−1.50	−1.23	−1.60	−1.43	−1.27	−1.53	−1.31	−1.44	−0.90	−1.13	−0.57	−0.49
+1.53	+1.29	+0.54	−1.04	−1.50	−0.90	−0.50	−0.91	−0.91	−1.21	−1.00	−0.86	−1.10	−1.03	−1.16	−1.27
−2.17	−1.64	−1.41	−1.03	−0.91	−0.30	−2.16	−0.89	−0.60	−0.81	−1.20	−1.47	−1.64	−1.83	−1.31	−1.27

TABLE II.—*Data of trial of new and old torpedo-boat watches at United States*

[The signs are astronomical, + losing; − gaining. Data of

									Mean daily rates.			
									Special temperatures (orientation not changed).			
Temperature.........degrees F..									90	85	70	55
Relative humidity by sling psychrometer.........per cent..									23	25	34	45
Order of merit.	Balance: o=ordinary. v=invar. Hairspring: p=palladium. s=steel.			Balance, hairspring.	Trial number.	Point of compensation.			Feb. 5 to 12.	Feb. 13 to 20.	Feb. 21 to 28.	Mar. 1 to 8.
	Watch.		Kind.			Temperature.	Rate.	Temperature constant.				
	New.					°	s.	s.	s.	s.	s.	s.
1	Longines [1]......	2059736	T. B. W.	o. s.	13.53	63.4	+1.07	+0.00071	+1.04	+0.77	+0.73	+1.00
2	Longines.......	2352417	T. B. W.	o. s.	13.58	39.2	+0.35	+0.00069	+1.89	+1.61	+0.70	+0.44
3	Longines [2]......	2388122	T. B. W.	o. s.	14.31	76.9	+2.52	+0.00109	+2.30	+2.64	+2.50	+2.91
4	Longines.......	2965529	T. B. W.	o. s.	17.25	26.5	+0.67	−0.00022	−0.29	−0.40	0.00	+0.83
5	Longines [2]......	2059718	T. B. W.	o. s.	22.46	45.2	+2.12	+0.00073	+3.21	+2.79	+2.27	+2.17
6	Longines.......	2517915	T. B. W.	o. s.	24.11	48.7	−3.15	+0.00084	−1.53	−1.79	−2.50	−3.04
	Old.											
1	Patek Philippe.	178464	T. B. W.	v. s.	18.81	81.2	+0.27	+0.00062	+0.77	+0.51	+0.26	+0.73

[1] Allowance made for acceleration during first 10 weeks.

[2] Eleventh week lacking. Value assumed in computing trial number.

Naval Observatory, Washington, D. C., February 5, 1920, to July 9, 1920.

watches with trial numbers greater than 25 omitted.]

Mean daily rates.															
Special temperatures (orientation not changed).						Ordinary temperatures (orientation changed).									
50	50	55	70	85	90	67.4	67.6	67.4	69.1	69.5	69.8	72.9	73.0	73.6	75.1
49	52	53	40	38	32	51	61	58	60	67	69	70	71	72	63
Mar. 9 to 16.	Mar. 16 to 23.	Mar. 25 to Apr. 1.	Apr. 3 to 10.	Apr. 12 to 19.	Apr. 21 to 28.	Apr. 30 to May 7.	May 7 to 14.	May 14 to 21.	May 21 to 28.	May 28 to June 4.	June 4 to 11.	June 11 to 18.	June 18 to 25.	June 25 to July 2.	July 2 to 9.
s.	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*
+0.93	+1.07	+1.23	+1.46	+2.03	+2.01	+0.89	+1 11	+1.03	+1.40	+1.40	+1.13	+1.74	+1.63	+1.81	+1.86
+0.30	+0.16	+0.59	+1.31	+1.97	+2.11	+0.81	+0.66	+0.64	+0.71	+1.07	+0.91	+1.37	+1.36	+1.26	+1.40
+2.90	+2.43	+3.16	+2.64	+2.54	+2.57	......	+3.26	+3.27	+3.46	+3.89	+3.71	+3.73	+3.63	+3.83	+3.50
+0.90	+0.91	+0.13	+0.47	+0.19	+0.09	+0.54	+0.74	+0.73	+0.74	+0.60	+0.63	+0.34	+0.10	+0.07	−0.07
+2.19	+1.91	+2.21	+2.87	+3.76	+4.04	......	+2.71	+2.86	+3.06	+3.33	+3.46	+3.63	+3.56	+3.66	+3.70
−3.03	−3.24	−3.19	−3.04	−2.30	−2.34	−3.01	−3.17	−3.21	−3.17	−2.83	−2.60	−2.03	−2.11	−2.24	−2.26
+0.64	+0.81	+0.66	+0.44	+0.04	+0.29	−0.30	+0.77	+0.07	+0.11	+0.04	+0.21	−0.19	−0.43	−0.54	−0.61

TABLE III.—*Data of trial of old chronometers at United States Naval*

[The signs are astronomical, + losing. − gaining; Data of

									Mean daily rates.			
									Special temperatures (orientation not changed.)			
	Temperature ... degrees F..								90	85	70	55
	Relative humidity by sling psychrometer ... per cent..								50.5	55.5	50.0	63.5
Order of merit.	Balance: o.=ordinary. v.=invar. a.=auxiliary. Hairspring: p.=palladium. s.=steel.			Balance, hairspring.	Trial number.	Point of compensation.			July 24 to 31.	Aug. 2 to 9.	Aug. 11 to 18.	Aug. 21 to 28.
	Chronometer.		Kind.			Temperature.	Rate.	Temperature constant.				
						°	s.	s.	s.	s.	s.	s.
1	Negus....	2180	M. T. S.	o. p.	3.52	67.0	+1.64	−0.00044	+1.56	+1.57	+1.73	+1.57
2	Nardin...	1263 1279	M. T. S.	v. s.	3.68	55.0	−0.74	+0.00036	−0.14	−0.41	−0.81	−0.77
3	Negus....	2192	M. T. S.	o. p.	4.73	69.7	+1.50	+0.00102	+1.64	+1.67	+1.31	+1.69
4	Negus....	2176	M. T. S.	o. p.	5.53	94.3	−2.87	+0.00056	−2.87	−2.89	−2.50	−2.06
5	Negus....	2253	M. T. S.	o. p.	7.94	90.8	−1.81	+0.00080	−1.67	−1.67	−1.37	−0.81
6	Crisp.....	3021	M. T. S.	o. s.	8.53	66.0	+0.24	+0.00211	+1.14	+0.87	+0.23	+0.47
7	Negus....	2227	M. T. S.	o. p.	9.69	68.1	−1.04	−0.00113	−1.07	−1.46	−1.14	−1.16
8	Knoblich.	2405	M. T. S.	o. s.	11.84	277.0	+8.13	+0.00011	+1.90	+1.36	+0.09	−1.00
9	Hand	1015 9318	M. T. S.	a. s	12.12	54.8	−2.67	+0.00073	−1.41	−2.06	−2.46	−2.67
10	Negus....	2141	M. T. S.	o. s.	12.16	−28.5	−3.21	+0.00033	+1.54	+1.10	+0.13	−0.97
11	Negus....	1265	M. T. S.	o. s.	14.86	65.1	+1.00	+0.00253	+2.37	+2.00	+0.89	+1.26
12	Negus....	1890	M.T.B.C.	o. s.	15.06	74.2	−1.60	+0.00224	−1.44	−1.29	−1.41	−0.71
13	Negus....	1752	M. T. S.	o. s.	15.65	62.2	−1.89	+0.00291	+0.20	−0.41	−1.53	−1.73
14	Negus....	1470	S. B. C.	o. s.	15.98	66.8	−0.51	+0.00231	+0.31	+0.44	−0.21	−0.11
15	Negus....	1595	M. T. S.	o. s.	16.38	69.0	+1.23	+0.00280	+1.97	+1.86	+1.17	+1.81
16	Nardin...	648	M. T. S.	v. s.	17.49	57.1	+0.12	+0.00049	+0.84	+0.61	+0.04	+0.13
17	Negus....	1975	M. T. S.	o. p.	17.80	41.3	−1.77	+0.00080	+0.53	−0.01	−1.14	−1.71
18	Negus....	1178	M.T.B.C.	o. s.	18.04	48.1	−3.36	+0.00207	+0.20	−0.40	−2.33	−3.24
19	Sewill....	4823	M. T. S.	o. s.	18.40	45.7	−0.25	+0.00151	+2.59	+2.11	+0.77	−0.07
20	Bond.....	495	M. T. S.	o. s.	18.87	65.6	−2.30	+0.00107	−1.56	−2.19	−2.64	−2.60
21	Negus....	772	M. T. S.	o. s.	19.33	65.6	+1.34	+0.00302	+2.56	+2.41	+1.41	+1.60
22	Bliss.....	3145	M. T. S.	o. p.	19.66	−108.5	+2.54	−0.00011	−0.26	+0.34	+0.76	+1.27
23	Bliss	3196	M. T. S.	o. p.	21.10	75.4	−1.96	+0.00124	−1.53	−1.81	−2.31	−1.66
24	Hand	1017 9345	M. T. S.	a. s.	22.70	72.4	−2.44	+0.00302	−1.56	−1.83	−2.54	−1.56
25	Negus....	1518	S. B. C.	o. s.	24.91	61.9	−2.89	+0.00287	−0.97	−1.26	−2.57	−2.66
26	Falconer..	4843	M. T. S.	o. s.	26.90	71.0	−0.94	+0.00329	+0.30	−0.30	−0.90	0.00
27	Bond.....	562	M. T. S.	o. s.	26.96	56.8	−1.79	+0.00316	+1.40	+0.91	−0.97	−1.71
28	Bliss.....	3175	M. T. S.	o. p.	29.29	66.8	−1.15	+0.00249	−0.20	−0.36	−1.33	−0.79
29	Negus....	1807	M. T. S.	o. s.	30.98	75.2	−0.99	+0.00371	−1.00	−0.87	−0.84	+0.50

NOTE.—All rates at 50° F. were lacking on this trial. In computing the trial numbers theoretical terms were used to give the trial numbers the same values as they probably would have had if the test had been conducted in the regular manner.

Observatory Washington, D. C., July 24 to December 15, 1920.

chronometers with trial number greater than 35 omitted.]

Mean daily rates.													
Special temperatures (orientation not changed).				Ordinary temperatures (orientation changed).									
55	70	85	90	64.5	69.9	72.1	68.2	64.0	61.5	60.3	58.4	58.5	58.4
64.0	64.5	55.5	57.0	65.0	69.5	72.0	64.0	65.0	62.5	63.0	58.3	60.5	55.0
Aug. 28 to Sept. 4.	Sept. 6 to 13.	Sept. 15 to 22.	Sept. 24 to Oct. 1.	Oct. 6 to 13.	Oct. 13 to 20.	Oct. 20 to 27.	Oct. 27 to Nov. 3.	Nov. 3 to 10.	Nov. 10 to 17.	Nov. 17 to 24.	Nov. 24 to Dec. 1.	Dec. 1 to 8.	Dec. 8 to 15.
s.	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*
+1.60	+1.56	+1.43	+1.40	+1.59	+1.50	+1.47	+1.53	+1.54	+1.74	+1.81	+1.94	+1.63	+1.77
−0.70	−0.51	−0.44	−0.51	−0.71	−0.53	−0.49	−0.47	−0.41	−0.46	−0.64	−0.74	−0.54	−0.64
+1.76	+1.69	+1.81	+1.84	+1.71	+1.90	+1.81	+1.69	+1.94	+2.13	+2.13	+2.14	+2 07	+2.11
−1.96	−2.57	−2.76	−2.93	−2.94	−3.10	−3.04	−2.83	−2.73	−2.50	−2.67	−2.67	−2.79	−2.79
−0.74	−1.56	−1.89	−1.90	−0.96	−1.14	−1.23	−0.94	−0.93	−0.84	−0 94	−0.94	−0.93	−0.99
+0.51	+0.31	+1.14	+1.34	+0.59	+0.72	+0.69	+0.66	+0.79	+0.77	+0.79	+0.80	+0.79	+0.70
−1.30	−0.94	−1.27	−1.14	−1.20	−1.60	−1.14	−1.43	−1.50	−1.67	−1.73	−1.39	−1.36	−1.50
−1.10	+0.09	+1.20	+1.46	−0.30	+0.31	+0.40	−0.01	−0.29	−0.44	−0.60	−0.49	−0.53	−0.51
−2.67	−2.53	−1.93	−2.07	−3.37	−3.11	−2.89	−3.70	−2.87	−3.53	−3.44	−3.33	−3.20	−2.99
−0.81	−0.09	+1.06	+1.61	+0.11	+0.13	+0.26	+0.20	+0.09	+0.03	−0.19	−0.17	−0.04	−0.13
+1.26	+1.23	+1.99	+2.71	+1.14	+1.51	+1.63	+1.03	+0.94	+1.03	+1.11	+1.06	+1.03	+1.13
−0.83	−1.31	−1.40	−1.23	−1.36	−2.01	−2.17	−1.83	−1.47	−1.23	−1.36	−1.53	−1.61	−1.57
−1.74	−1.89	−0.33	+0.36	−1.93	−1.90	−1.76	−1.90	−2.07	−1.90	−2.01	−2 00	−2.01	−1.93
−0.27	−0.77	+0.06	+0.34	−1.39	−1.26	−1.17	−1.10	−1.10	−0.81	−0.81	−0.83	−0.83	−0.97
+1.76	+1.29	+2.03	+2.54	+1.63	+1.64	+1.71	+1.59	+1.44	+1.34	+1.37	+1.57	+1.40	+1.37
+0.10	+0.36	+0.39	+0.13	−0.43	+0.24	+0.64	+0.29	0.00	+0.04	+0.14	+0.84	+0.59	+0.21
−1.53	−1.07	−0.46	−0.51	−1.64	−0.89	−0.71	−1.20	−1.26	−1.80	−1.69	−1.49	−1.67	−1.37
−3.27	−2.41	−0.70	+0.29	−2.71	−2.69	−2.56	−2.80	−3.01	−3.31	−3.37	−3.37	−3.49	−3.50
−0.17	+0.51	+2.06	+2.96	+0.17	+0.23	+0.34	+0.10	−0.36	−0.23	−0.69	−0.70	−0.91	−0.86
−1.76	−1.93	−1.61	−1.49	−1.29	−1.10	−1.10	−0.99	−1.03	−1.41	−1.51	−1.56	−1.53	−1.57
+1.76	+1.39	+2.54	+3.49	+1.53	+1.64	+1.67	+1.63	+1.56	+1.69	+1.33	+1.41	+1.50	+1.40
+1.39	+0.76	−0.07	−0.43	+1.10	+1.11	+0.71	+0.70	+0.76	+0.93	+0.80	+0.54	+0.51	+0.47
−1.23	−1.53	−1.86	−1.97	−1.77	−1.19	−1.19	−0.99	−1.20	−1.47	−1.66	−1.57	−1.47	−1.59
−1.47	−2.31	−2.10	−1.60	−2.31	−2.11	−2.29	−2.27	−2.59	−1.20	−2.06	−1.81	−2.06	−1.96
−2.84	−2.83	−1.47	−1.04	−2.54	−2.73	−2.50	−2.84	−3.07	−3.09	−3.24	−3.30	−3.41	−3.37
−0.21	−0.97	−0.30	+0.13	−0.77	−1.13	−1.17	−1.01	+0.27	−1.17	−0.53	−0.47	−0.44	−0.43
−1.84	−1.51	+0.53	+1.40	−1.40	−0.96	−1.09	−1.17	−1.46	−1.73	−1.91	−1.71	−1.81	−1.86
−0.81	−0.90	−0.27	−0.17	−0.71	−0.01	−0.51	−1.16	−1.31	−1.43	−1.10	−1.00	−1.09	−0.93
+0.53	−0.94	−0.39	−0.23	−0.23	−0.74	−0.89	−0.43	−0.14	+0.37	+0.54	+0.74	+0.51	+0.61

TABLE IV.—*Data of trial of new and old torpedo boat watches at United*

[The signs are astronomical, +losing; −gaining. Data of new watches with trial numbers

									Mean daily rates.			
									Special temperatures (orientation not changed).			
Temperature....degrees F..									90	85	70	55
Relative humidity by sling psychrometer....per cent..									50.5	55.5	50.0	63.5
Order of merit.	Balance: o=ordinary. v=invar. Hairspring: p=palladium. s=steel.			Balance, hairspring.	Trial number.	Point of compensation.			July 24 to 31.	Aug. 2 to 9.	Aug. 11 to 18.	Aug. 21 to 28.
	Watch.		Kind.			Temperature.	Rate.	Temperature constant.				
	New.											
						°	s.	s.	s.	s.	s.	s.
1	Longines...	2965511	T. B. W.	v. s.	5.90	92.5	+2.99	+0.00049	+3.00	+3.07	+3.07	+3.73
2	Hamilton ..	1260448	T. B. W.	v. s.	8.50	212.6	+1.48	−0.00007	+0.13	+0.17	−0.14	−0.23
3	Longines...	2517930	T. B. W.	v. s.	8.54	50.9	−1.63	+0.00049	−0.77	−1.04	−1.27	−1.64
4	Hamilton...	1260449	T. B. W.	v. s.	14.60	85.0	+0.20	−0.00009	−1.20	−0.11	−0.27	−0.27
5	Hamilton...	1260443	T. B. W.	v. s.	17.96	85.1	+3.44	−0.00113	+3.56	+3.14	+2.84	+2.41
	Old.											
1	Ditisheim...	45066	T. B. W.	v. s.	8.27	125.0	+0.08	+0.00013	−0.13	+0.31	+0.41	+0.94
2	Hamilton...	Ⓝ5212	T. B. W.	v. s.	11.84	64.2	−0.02	+0.00231	+1.61	+0.93	−0.21	+0.16
3	Longines...	2059751	T. B. W.	v. s.	15.03	109.6	+1.37	−0.00031	+1.70	+1.33	+1.07	+0.73
4	Hamilton...	Ⓝ5201	T. B. W.	v. s.	15.23	79.9	−1.08	+0.00227	−0.83	−1.07	−1.13	+0.24
5	Hamilton...	Ⓝ5127	T. B. W.	s. s.	16.63	81.9	−0.68	+0.00213	−0.69	−0.83	−0.57	+0.86
6	Longines...	Ⓝ4418	T. B. W.	v. s.	16.84	69.3	−1.30	+0.00224	+0.20	−0.71	−1.53	−0.89
7	Longines...	Ⓝ4419	T. B. W.	v. s.	21.67	67.1	−1.04	+0.00369	+0.57	+0.07	−1.31	−0.59
8	Hamilton...	Ⓝ5207	T. B. W.	v. s.	22.75	81.6	−0.45	+0.00233	−0.36	−0.56	−0.27	+1.11
9	Longines...	Ⓝ4002	T. B. W.	v. s.	25.20	32.9	−0.79	+0.00091	+2.08	+1.49	+0.49	−0.27
10	Hamilton...	Ⓝ5210	T. B. W.	v. s.	26.74	63.8	−0.16	+0.00209	+1.64	+0.74	−0.34	−0.04
11	Longines...	Ⓝ4003	T. B. W.	v. s.	32.22	62.5	−1.32	+0.00131	+0.71	−0.49	−1.17	−1.31
12	Hamilton...	Ⓝ5108	T. B. W.	s. s.	32.76	84.9	+0.05	+0.00229	+0.30	−0.06	+0.51	+2.10
13	Hamilton ..	Ⓝ5225	T. B. W.	v. s.	33.08	74.3	−0.04	+0.00209	+0.54	+0.16	−0.01	+0.86

NOTE.—All rates at 50° F. and on 2 watches one rate at ordinary temperature were lacking in this trial. In computing the trial numbers, theoretical terms were used to give the trial numbers the same value as they probably would have had if the test had been conducted in the regular manner.

States Naval Observatory, Washington, D. C., July 24 to December 15, 1920.

greater than 25 omitted; data of old watches with trial numbers greater than 35 omitted.]

Mean daily rates.													
Special temperatures (orientation not changed).				Ordinary temperatures (orientation changed).									
55	70	85	90	64.5	69.9	72.1	68.2	64.0	61.5	60.3	58.4	58.5	58.4
64.0	64.5	55.5	57.0	65.0	69.5	72.0	64.0	65.0	62.5	63.0	59.3	60.5	55.0
Aug. 28 to Sept. 4.	Sept. 6 to 13.	Sept. 15 to 22.	Sept. 24 to Oct. 1.	Oct. 6 to 13.	Oct. 13 to 20.	Oct. 20 to 27.	Oct. 27 to Nov. 3.	Nov. 3 to 10.	Nov. 10 to 17.	Nov. 17 to 24.	Nov. 24 to Dec. 1.	Dec. 1 to 8.	Dec. 8 to 15.
s.	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*
+3.63	+3.41	+2.96	+2.74	+3.50	+3.56	+3.54	+3.41	+3.74	....	+3.74	+3.96	+3.83	+3.61
−0.11	+0.40	+0.64	+0.20	+0.19	+0.46	+0.51	+0.33	+0.11	+0.10	+0.13	+0.20	+0.10	+0.11
−1.59	−1.63	−1.07	−1.49	−1.61	−1.51	−1.23	−1.41	−1.87	....	−1.40	−1.26	−1.39	−1.49
−0.29	−0.16	−0.30	−0.63	−0.16	+0.21	+0.36	0.00	+0.04	+0.13	+0.09	+0.19	+0.14	+0.49
+2.41	+3.53	+3.73	+3.74	+2.74	+3.26	+3.36	+3.54	+3.37	+3.21	+2.96	+3.31	+2.91	+3.06
+0.56	+0.59	+0.31	+0.20	+0.61	+1.20	+0.87	+0.66	+1.05	+0.80	+0.73	+0.93	+0.91	+0.83
+0.21	+0.34	+1.04	+1.54	−0.26	+0.03	+0.11	−0.10	−0.17	−0.20	−0.30	−0.16	−0.14	−0.17
+0.24	+0.76	+1.11	+1.06	+0.13	+0.91	+0.84	+0.74	+1.03	+0.74	+0.81	+0.86	+0.63	+0.90
+0.40	−0.60	−0.96	−1.21	−0.46	−1.01	−0.96	−0.93	−0.46	−0.27	−0 39	−0.19	−0.24	−0.24
+0.86	−0.19	−0.50	−0.80	+0.44	+0.43	+0.07	+0.29	+0.26	+1.07	+1.07	+1.20	+1.17	+1.33
−0.79	−1.07	−0.79	−0.39	−1.79	−1.36	−1.36	−1.20	−1.23	−1.57	−1.80	−1.67	−1.34	−1.47
−0.40	−0.71	+0.20	+0.64	−0.43	−0.64	−0.46	−0.37	−0.44	−0.44	−0.49	−0.14	−0.31	−0.11
+1.30	0.00	−0.30	−0.50	−0.19	−0.27	−0.49	−0.01	+0.03	−0.11	+0.11	+0.19	0.00	−0.19
−0.43	+0.43	+1.86	+2.01	+0.04	+0.44	+0.60	−0.26	−0.93	−0.41	−1.09	−0.63	−0.73	−1.21
+0.03	+0.19	+0.81	+0.83	−0.44	−0.27	−0.03	−1.11	−1.34	−0.81	−0.89	−0.97	−1.06	−1.12
−1.16	−1.31	−0.81	−0.87	−2.30	−1.33	−0.61	−1.23	−1.36	−1.60	−1.77	−1.24	−1.46	−1.59
+2.11	+0.61	+0.16	−0.04	+0.89	+0.71	+0.54	+0.93	+1.39	+2.49	+2.33	+2.61	+2.40	+2.57
+0.61	+0.01	+0.23	+0.54	+0.27	+0.83	+0.79	+0.50	+0.74	+0.30	−0.17	+0.31	+0.07	−0.09

TABLE V.—*Data of trial of old chronometers at United States Naval*

[The signs are astronomical, + losing; − gaining. Data of

									Mean daily rates.			
									Special temperatures (orientation not changed).			
Temperature..........degrees F..									90	85	70	55
Relative humidity by sling psychrometer..........per cent..									32	35	39	44
Order of merit.	Balance: o=ordinary. v=invar. a=auxiliary. Hairspring: p=palladium. s=steel. Chronometer.		Kind.	Balance, hair-spring.	Trial number.	Point of compensation. Temperature.	Rate.	Temperature constant.	Jan. 27 to Feb. 3.	Feb. 5 to 12.	Feb. 14 to 21.	Feb. 24 to Mar. 3.
						°	s.	s.	s.	s.	s.	s.
1	Bliss............	2971	M. T. S.	o. p.	6.48	45.0	−0.37	+0.00027	+0.16	−0.17	−0.11	−0.39
2	.....do..........	3113	M. T. S.	v. s.	7.20	∞	......	....	+1.29	+1.20	+1.66	+1.76
3	Negus..........	2222	M. T. S.	o. p.	9.83	94.6	−1.74	+0.00031	−0.99	−1.43	+1.46	−1.36
4	.....do..........	2181	M. T. S.	o. p.	10.39	81.8	−0.92	−0.00031	−0.31	−0.56	−0.76	−1.26
5	.....do..........	2239	M. T. S.	o. p.	10.68	68.9	+0.92	−0.00031	+1.03	+0.91	+1.16	+0.81
6	Bond...........	1014	M. T. S.	o. s.	11.41	62.5	−1.43	+0.00164	+0.23	−0.44	−1.24	−1.20
7	Bliss............	3129	M. T. S.	o. p.	11.48	34.6	−1.77	+0.00047	−0.41	−0.53	−1.03	−1.23
8	Bond...........	283	M. T. S.	o. s.	11.77	42.4	−1.93	+0.00104	+0.37	0.00	−0.99	−1.80
9	Negus..........	2199	M. T. S.	o. p.	11.95	55.5	+1.18	+0.00062	+2.07	+1.77	+1.31	+0.93
10	.....do..........	2225	M. T. S.	o. p.	12.30	71.3	−0.38	−0.00038	+0.37	−0.20	−0.26	−0.80
11	.....do..........	2219	M. T. S.	o. p.	12.37	79.8	+0.18	−0.00058	+0.10	0.00	−0.03	−0.29
12	Bliss............	3121	M. T. S.	v. s.	12.66	542.5	−11.51	+0.00004	−2.24	−2.17	−1.46	−1.23
13	Negus..........	2224	M. T. S.	o. p.	13.85	88.8	−3.00	+0.00018	−3.27	−3.00	−2.66	−2.94
14	.....do..........	1155	M. T. S.	o. s.	14.21	59.1	+0.47	+0.00173	+1.71	+1.57	+1.00	+0.64
15	.....do..........	1970	M. T. S.	o. p.	14.36	54.7	−0.86	+0.00051	−1.01	−0.67	−0.79	−1.00
16	.....do..........	1721	M. T. S.	o. s.	14.59	67.3	−0.96	+0.00249	+0.37	−0.29	−1.00	−0.50
17	.....do..........	1287	M. T. S.	o. s.	16.10	75.2	−0.09	+0.00178	+0.79	+0.17	+0.17	+0.70
18	Bond...........	529	M. T. S.	o. s.	16.30	50.6	−0.67	+0.00169	+1.31	+1.34	−0.06	−0.77
19	.....do..........	1054	M. T. S.	o. s.	16.58	67.8	+0.83	+0.00302	+1.71	+1.67	+0.94	+1.34
20	Negus..........	1984	M. T. S.	o. s.	16.72	65.3	+0.19	+0.00336	+1.87	+1.41	+0.23	+0.61
21	.....do..........	2115	M. T. S.	o. s.	17.23	66.6	−0.04	+0.00329	+1.71	+1.23	0.00	+0.17
22	.....do..........	1890	S. B. C.	o. s.	18.06	67.9	−2.41	+0.00324	−0.89	−1.47	−2.40	−1.81
23	Bliss............	3116	M. T. S.	v. s.	18.41	77.5	+0.32	+0.00044	+0.39	+0.17	+0.50	+0.63
24	Bond...........	585	M.T.B.C.	o. s.	19.89	65.9	+0.94	+0.00158	+1.60	+1.54	+0.61	+1.00
25	.....do..........	560	M. T. S.	o. s.	20.03	73.3	−1.57	+0.00344	−0.83	−1.00	−1.26	−0.39
26	Negus..........	2205	M. T. S.	o. p.	20.61	169.0	+0.45	−0.00022	−1.11	−1.33	−1.47	−2.67
27	Bliss............	3062	M. T. S.	o. s.	20.95	71.7	+0.07	+0.00231	+1.16	+0.64	+0.09	+0.57
28	Bond...........	620	M. T. S.	o. s.	22.05	65.6	−1.74	+0.00244	−0.20	−0.66	−1.64	−1.47
29	Negus..........	2163	M. T. S.	o. p.	22.19	56.7	−1.96	+0.00102	−0.20	−0.69	−1.41	−2.03
30	.....do..........	1983	M. T. S.	o. s.	23.24	78.6	+1.90	+0.00264	+2.73	+1.96	+2.41	+3.33
31	Creighton & Black.........	2259	M. T. S.	o. s.	24.78	71.3	−0.05	+0.00360	+1.43	+0.79	+0.17	+0.76
32	Negus..........	2204	M. T. S.	o. p.	24.83	∞	......	....	0.00	+0.44	+0.59	+0.56
33	Kelvin, Bottomley & Baird...	9541	M. T. S.	o. s.	25.13	56.5	−0.94	+0.00056	+0.09	−0.64	−1.06	−1.36
34	Bliss............	3138	M. T. S.	o. p.	25.65	80.8	−0.72	+0.00071	−0.46	−0.73	−1.10	−0.64
35	.....do..........	3158	M. T. S.	o. p.	26.72	175.0	−4.06	+0.00009	−2.66	−3.71	−2.96	−2.50
36	Leroy...........	1171	M. T. S.	v. s.	27.37	78.0	−0.19	+0.00133	−0.10	−0.36	−0.14	+0.84
37	Ehrlich.........	598	M. T. S.	o. s.	27.46	74.5	+0.49	+0.00276	+0.81	+0.93	+0.70	+1.54
38	Lange...........	134	M. T. S.	v. s.	28.62	50.3	+0.05	−0.00036	−0.10	−0.40	−0.41	−0.33
39	Negus..........	2114	M. T. S.	o. s.	29.06	−233.8	-17.00	+0.00018	+2.03	+1.30	−0.19	−2.16
40	Bliss............	3163	M. T. S.	o. p.	29.13	63.4	+0.50	+0.00073	+1.09	+0.93	+0.53	+0.33
41	Bond...........	490	M. T. S.	o. s.	29.95	37.7	+1.81	−0.00089	+0.37	+0.50	+0.90	+1.51
42	Negus..........	1898	M. T. S.	o. s.	32.97	67.7	+0.09	+0.00244	+1.74	+0.86	+0.30	+0.33
43	.....do..........	1444	M. T. S.	o. s.	33.31	67.7	−1.41	+0.00220	−0.16	+0.61	−1.10	−1.04
44	.....do..........	2200	M. T. S.	o. p.	34.76	79.3	−1.09	+0.00127	−1.36	−1.11	−0.47	0.00

Observatory, Washington, D. C., January 27 to July 6, 1921.

chronometers with trial numbers greater than 35 omitted.]

Mean daily rates—Continued.															
Special temperatures (orientation not changed).						Ordinary temperatures (orientation changed).									
50	50	55	70	85	90	67.3	64.7	65.6	67.1	68.4	70.1	71,1	74.1	77.3	79.9
58	56	52	60	38	37	58	57	61	68	67	66	65	64	73	68
Mar. 5 to 12.	Mar. 12 to 19.	Mar. 21 to 28.	Mar. 30 to Apr. 6.	Apr. 8 to 15.	Apr. 18 to 25.	Apr. 27 to May 4.	May 4 to 11.	May 11 to 18.	May 18 to 25.	May 25 to June 1.	June 1 to 8.	June 8 to 15.	June 15 to 22.	June 22 to 29.	June 29 to July 6.
s.	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*
-0.27	-0.16	-0.29	-0.30	+0.29	-0.10	+0.13	-0.13	-0.26	-0.26	-0.34	-0.29	-0.40	-0.24	0.00	-0.11
+1.76	+1.99	+1.76	+1.29	+1.21	+1.06	+1.63	+1.80	+1.89	+1.90	+1.76	+1.86	+2.04	+2.06	+1.76	+2.03
-1.03	-0.83	-1.14	-1.64	-1.99	-2.33	-2.03	-1.96	-1.93	-1.99	-2.11	-2.11	-2.29	-2.24	-2.23	-2.30
-1.01	-1.09	-1.03	-1.17	-1.27	-1.47	-1.47	-1.41	-1.40	-1.50	-1.57	-1.54	-1.71	-1.53	-1.54	-1.56
+1.16	+1.03	+0.91	+0.67	+0.76	+0.53	+0.64	+0.71	+0.90	+0.71	+0.43	+0.26	+0.19	+0.24	+0.17	+0.04
-1.06	-1.06	-1.47	-1.43	-0.76	-0.33	-1.54	-1.60	-1.47	-1.10	-1.19	-1.53	-1.11	-0.93	-1.00	-0.77
-1.44	-1.64	-1.91	-1.34	-0.64	-0.40	-0.70	-1.04	-1.10	-1.00	-1.01	-1.17	-1.13	-0.91	-0.91	-0.81
-1.50	-1.57	-1.73	-1.27	-0.06	+0.37	-0.70	-0.81	-0.79	-0.61	-0.34	-0.36	-0.37	-0.29	-0.09	+0.51
+1.41	+1.60	+1.43	+1.31	+1.67	+1.64	+1.47	+1.77	+2.09	+2.40	+2.06	+1.89	+1.97	+1.80	+1.89	+2.09
-0.54	-0.39	-0.17	-0.50	-0.70	-0.81	-0.74	-0.40	-0.29	-0.33	-0.41	-0.47	-0.59	-0.66	-0.86	-0.69
-0.13	-0.11	-0.07	+0.27	+0.33	-0.03	+0.19	+0.31	+0.24	+0.20	+0.04	+0.16	-0.21	-0.36	-0.37	-0.20
-0.67	-0.57	-0.69	-1.74	-2.26	-2.57	-1.70	-1.59	-1.79	-1.60	-1.73	-1.70	-1.69	-1.69	-1.66	-1.66
-2.19	-1.93	-2.66	-3.21	-2.99	-2.66	-3.16	-2.93	-2.47	-2.43	-2.67	-2.40	-2.59	-2.61	-2.59	-2.81
+0.57	+0.50	+0.31	+0.33	+1.67	+2.56	+0.40	+0.19	+0.29	+0.24	+0.43	+0.43	+0.31	+0.54	+0.69	+0.73
-0.90	-0.83	-0.71	-0.69	-0.11	-0.21	-0.70	+0.03	-0.47	-0.76	-0.66	-0.69	-0.79	-0.66	-0.59	-0.51
-0.13	-0.30	-0.64	-0.89	-0.07	+0.33	-0.63	-0.79	-0.76	-0.96	-1.03	-1.11	-1.06	-1.13	-0.86	-1.14
+1.79	+1.87	+0.57	-0.26	-0.01	+0.57	-0.14	-0.07	-0.19	-0.37	-0.31	-0.24	-0.26	-0.67	-0.57	-0.43
-1.00	-0.86	-0.50	-0.01	+1.30	+2.51	-0.40	-0.61	-0.39	-0.29	-0.41	-0.41	-0.20	+0.10	+0.27	+0.51
+1.87	+1.84	+1.31	+0.74	+1.77	+2.86	+1.57	+1.57	+1.56	+1.26	+1.29	+1.39	+1.30	+1.39	+1.43	+1.56
+1.00	+0.93	+0.47	+0.30	+1.57	+2.17	+0.47	+0.27	+0.21	+0.36	+0.40	+0.39	+0.47	+0.57	+0.79	+0.93
+0.87	+0.87	+0.63	0.00	+0.94	+1.69	+0.69	+0.61	+0.64	+0.69	+0.93	+0.96	+0.81	+1.17	+1.11	+1.44
-1.29	-1.41	-1.93	-2.41	......	-0.91	-2.50	-2.49	-2.19	-2.37	-2.73	-2.79	-2.76	-2.53	-2.64	-2.54
+0.99	+0.93	+0.44	+0.17	+0.51	+0.26	+0.70	+0.84	+1.10	+1.21	+1.23	+1.29	+1.20	+1.16	+1.29	+2.17
+1.90	+1.94	+1.26	+1.33	+1.50	+2.01	+1.36	+0.60	+0.59	+0.74	+1.14	+1.46	+1.29	+1.19	+1.39	+1.46
+0.20	-0.14	-0.43	-1.80	-1.20	-0.74	-1.79	-1.76	-1.60	-1.90	-1.89	-1.74	-2.13	-2.03	-2.09	-2.04
-2.39	-2.29	-2.21	-1.99	-0.91	-1.06	-1.43	-1.50	-1.46	-1.43	-1.50	-1.47	-1.63	-1.64	-1.79	-1.77
+1.73	+1.79	+0.87	+0.07	+0.33	+1.14	+0.81	+0.96	+0.93	+0.93	+1.19	+1.10	+1.23	+1.31	+1.54	+1.97
-0.17	-0.97	-1.46	-1.74	-0.97	-0.13	-1.26	-1.74	-1.33	-1.17	-1.21	-0.90	-0.96	-0.67	-0.40	-0.34
-1.54	-1.63	-1.89	-2.16	-1.60	-1.10	-1.99	-1.76	-1.54	-1.63	-1.69	-1.71	-1.57	-1.71	-1.71	-1.84
+4.51	+4.41	+3.44	+1.79	+2.06	+2.97	+2.26	+2.39	+2.27	+1.76	+2.04	+2.10	+1.64	+1.64	+1.64	+1.80
+1.53	+1.39	+1.06	-0.24	+0.47	+1.06	+0.36	+0.50	+0.49	+0.43	+0.61	+0.33	+0.43	+0.74	+1.19	+1.31
+0.40	+0.51	+0.23	+0.54	+0.99	+1.07	+0.41	-0.59	-0.76	-0.46	-0.71	-0.76	-1.10	-1.07	-0.80	-0.60
-0.84	+0.09	-0.53	-0.61	-0.34	-0.04	-1.29	-0.54	-0.69	-0.74	-0.79	-0.76	-0.73	-0.31	-0.10	+0.19
+0.06	+0.19	+0.14	-0.19	-0.69	-0.31	-0.80	-0.27	+0.21	+0.20	+0.23	+0.07	+0.11	+0.03	+0.19	+0.39
-3.20	-2.96	-3.06	-3.19	-2.96	-3.16	-3.07	-3.10	-2.64	-2.07	-2.26	-2.50	-2.57	-2.47	-2.39	-2.27
+0.84	+0.84	+0.21	-0.07	+0.11	+0.01	-0.11	-0.10	-0.11	-0.20	-0.29	+0.51	-0.10	+0.19	+0.71	+0.76
+2.54	+2.07	+1.53	+0.40	+0.67	+1.41	+1.09	+1.50	+0.96	+0.31	-0.03	+0.50	+0.23	+0.53	+0.63	+0.59
+0.70	+0.87	+0.41	+0.23	-0.36	-0.39	-0.89	+0.07	+0.13	+0.26	+0.21	+0.40	+0.39	+0.21	0.00	+0.29
-2.67	-2.47	-2.19	-1.01	+0.83	+1.67	-0.90	-1.10	-0.87	-0.31	+0.04	+0.14	-0.04	0.00	+0.40	+0.66
+1.27	+1.29	+0.77	+0.53	+0.76	+1.36	+0.74	+1.00	+1.74	+1.89	+2.00	+1.93	+2.04	+2.09	+2.06	+2.49
+1.83	+1.67	+1.57	+0.87	-0.86	-0.17	+0.29	+0.54	+0.53	+0.39	+0.29	-0.03	+0.14	-0.04	+0.19	-0.04
+0.71	+0.70	+0.64	-0.09	+0.77	+0.86	-0.44	-0.61	-0.17	-0.23	+0.04	+0.13	+0.11	+0.51	+0.84	+1.36
-0.44	-0.39	-1.07	-1.71	-0.89	+0.26	-1.61	-1.69	-2.09	-1.93	-1.74	-1.94	-1.51	-1.66	-1.13	-1.00
0.00	+0.04	-0.67	-1.49	-0.99	-0.59	-1.20	-0.36	+0.33	+0.24	-0.33	-0.69	-0.64	-0.97	-0.89	-0.89

TABLE VI.—*Data of trial of new and old torpedo-boat watches at United*

[The signs are astronomical, +losing; −gaining. Data of new watches with trial numbers

									Mean daily rates.			
									Special temperatures (orientation not changed).			
Temperature......degrees F..									90	85	70	55
Relative humidity by sling psychrometer......per cent..									32	35	39	44
Order of merit.	Balance: o=ordinary. v=invar. a=auxiliary. Hairspring: p=palladium. s=steel.			Balance, hairspring.	Trial number.	Point of compensation.			Jan. 27 to Feb. 3.	Feb. 5 to 12.	Feb. 14 to 21.	Feb. 24 to Mar. 3.
	Watch.		Kind.			Temperature.	Rate.	Temperature constant.				
	New.					°	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*
1	Longines......	2352421	T. B. W.	v. s.	10.87	99.1	+0.65	+0.00020	+0.76	+0.67	+0.70	+0.96
2	Longines......	2517939	T. B. W.	v. s.	13.13	58.0	−0.36	−0.00044	−0.73	−0.64	−0.44	−0.54
3	Ditisheim......	36134	T. B. W.	v. s.	13.85	81.6	+0.07	+0.00076	−0.11	−0.17	+0.10	+0.51
4	Longines......	2517934	T. B. W.	v. s.	15.14	111.8	+4.14	−0.00047	+4.31	+3.89	+3.24	+2.69
5	Hamilton......	1260445	T. B. W.	v. s.	16.06	145.0	+6.38	−0.00009	+1.57	+1.26	+1.17	+1.29
6	Longines......	2388120	T. B. W.	v. s.	16.99	76.2	−1.72	+0.00051	−1.10	−1.50	−1.81	−1.61
7	Longines......	2965523	T. B. W.	v. s.	17.23	302.5	−1.08	+0.00002	+0.54	+0.34	0.00	+0.23
8	Longines......	2965531	T. B. W.	v. s.	21.39	80.6	+2.10	+0.00149	+1.81	+1.97	+2.14	+2.99
	Old.											
1	Longines......	Ⓝ4079	T. B. W.	v. s.	19.85	67.8	−0.31	+0.00178	+1.01	+0.23	−0.34	−0.27
2	Hamilton......	Ⓝ5251	T. B. W.	v. s.	23.70	78.7	−1.31	+0.00116	−0.24	−1.40	−1.11	−0.77
3	Hamilton......	Ⓝ5207	T. B. W.	v. s.	24.95	79.3	−1.57	+0.00224	−1.19	−1.29	−1.44	−0.60
4	Hamilton......	Ⓝ5261	T. B. W.	v. s.	26.21	74.2	+0.02	+0.00231	+0.54	+0.07	−0.36	+0.41
5	Hamilton......	Ⓝ5212	T. B. W.	v. s.	29.59	64.8	−0.75	+0.00218	+1.56	+0.36	−0.77	−0.71

States Naval Observatory, Washington, D. C., January 27 to July 6, 1921.

greater than 25 omitted; data of old watches with trial numbers greater than 35 omitted.]

Mean daily rates.															
Special temperatures (orientation not changed).						Ordinary temperatures (orientation changed).									
50	50	55	70	85	90	67.3	64.7	65.6	67.1	68.4	70.1	71.1	74.1	77.3	79.9
58	56	52	60	38	37	58	57	61	68	67	66	65	64	73	68
Mar. 5 to 12.	Mar. 12 to 19.	Mar. 21 to 28.	Mar. 30 to Apr. 6.	Apr. 8 to 15.	Apr. 18 to 25.	Apr. 27 to May 4.	May 4 to 11.	May 11 to 18.	May 18 to 25.	May 25 to June 1.	June 1 to 8.	June 8 to 15.	June 15 to 22.	June 22 to 29.	June 29 to July 6.
s.	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*
+1.33	+1.44	+1.11	+0.93	+0.71	+0.33	0.00	+0.19	+0.24	+0.04	−0.03	+0.07	+0.21	+0.36	+0.49	+0.76
−0.19	−0.06	−0.17	−0.41	−0.73	−0.69	−0.70	−0.63	−0.36	−0.40	−0.29	−0.03	−0.26	−0.41	−0.81	−1.36
+1.01	+1.26	+0.69	+0.24	+0.33	−0.04	+0.07	+0.20	+0.54	+0.43	+0.24	+0.47	+0.40	+0.39	+0.79	+0.80
+2.54	+2.49	+2.57	+3.40	+3.70	+3.76	+3.17	+3.19	+3.19	+3.50	+3.61	+3.87	+4.01	+4.17	+4.31	+4.43
+1.17	+1.40	+1.04	+1.60	+1.87	+2.26	+2.13	+1.86	+1.90	+2.04	+2.40	+2.44	+2.50	+2.44	+2.61	+2.99
−0.89	−0.73	−1.37	−1.60	−1.87	−2.09	−1.97	−1.60	−1.71	−1.71	−1.61	−1.33	−1.41	−1.29	−1.21	−0.93
+0.44	+0.47	+0.34	+0.23	−0.40	−0.60	+0.39	+0.33	+0.50	+0.64	+0.47	+0.63	+0.66	+0.49	+0.37	−0.51
+3.73	+3.73	+3.17	+2.40	+2.29	+2.36	+3.41	+3.73	+3.66	+3.71	+3.93	+3.99	+4.20	+4.23	+4.01	+4.10
+0.54	+0.69	+0.24	−0.27	+0.21	−0.13	−1.16	−0.97	−0.71	−0.54	−0.31	−0.29	−0.51	−0.94	−0.44	−0.87
−0.20	−0.07	−0.54	−1.34	−1.11	−1.30	−1.43	−1.41	−0.71	−0.93	−0.89	−0.73	−1.37	−1.13	−0.96	−0.30
+1.01	+0.96	+0.10	−1.31	−1.70	−2.07	−1.64	−1.51	−1.31	−1.09	−1.44	−1.23	−1.46	−1.36	−1.67	−1.61
+1.50	+1.43	+1.33	+0.49	+0.51	+0.63	+0.41	+0.83	+0.97	+0.86	+1.09	+1.10	+0.70	+0.79	+1.11	+0.96
−0.64	−0.16	−0.36	−0.61	−0.07	+0.53	−1.06	−1.06	−0.93	−0.70	−0.40	−0.26	−0.16	−0.01	+0.29	+0.49

TABLE VII.—*Data of trial of old chronometers at United States Naval*

[The signs are astronomical: + losing; — gaining. Data of

Order of merit.	Balance: o=ordinary. v=invar. a=auxiliary. u=special. Hairspring: p=palladium. s=steel.			Trial number.	Balance, hairspring.	Point of compensation.			Mean daily rates.			
									Special temperatures.			
	Temperature ... degrees F..								90	85	70	55
	Relative humidity by sling psychrometer ... per cent..								35	39.5	46	50
	Chronometer.		Kind.			Temperature.	Rate.	Temperature constant.	Oct. 15 to 22.	Oct. 24 to 31.	Nov. 2 to 9.	Nov. 12 to 19.
						°	s.	s.	s.	s.	s.	s.
1	Nardin	601	M. T. S.	4.05	v. s.	41.7	−0.90	+0.00029	−0.41	−0.54	−0.80	−0.93
2	Negus	2250	M. T. S.	7.17	o. p.	98.9	+0.68	+0.00031	+0.93	+0.94	+0.79	+1.24
3	Negus	1985	M. T. S.	8.95	o. s.	142.9	−0.50	+0.00024	+0.27	+0.21	+0.61	+1.57
4	Bliss	3203	M. T. S.	9.56	o. p.	19.2	−0.45	+0.00038	+1.54	+1.17	+0.47	−0.01
5	Nardin	881	M. T. S.	10.98	v. s.	46.0	+0.93	+0.00067	+2.30	+2.06	+1.46	+0.99
6	Nardin	713	M. T. S.	11.94	v. s.	55.0	−1.96	+0.00009	−1.14	−1.54	−1.64	−2.00
7	Bliss	2934	M. T. S.	12.51	o. s.	77.2	−0.93	−0.00107	−0.91	−1.09	−1.34	−1.51
8	Bond	621	M. T. S.	12.69	o. s.	68.2	+1.77	+0.00280	+3.71	+2.69	+1.67	+2.26
9	Hand	1015 9318	M. T. S.	14.14	a. s.	103.2	−1.06	−0.00031	−0.79	−0.83	−1.60	−1.77
10	Bliss	3119	M. T. S.	15.22	v. s.	26.8	+0.45	−0.00029	−1.03	−0.50	+0.11	+0.49
11	Bond	307	M. T. S.	15.90	o. s.	71.4	−1.42	+0.00311	−0.43	−1.20	−1.36	−0.66
12	Knoblich	2305	M. T. S.	16.69	v. s.	58.4	−0.72	+0.00220	+1.39	+1.03	−0.34	−0.59
13	Reid	2210	M. T. S.	17.07	o. s.	72.2	+0.11	+0.00220	+1.50	+0.53	+0.33	+0.86
14	Union	55803	M. T. S.	17.21	v. s.	66.8	−0.24	−0.00016	−0.43	−0.19	+0.06	−0.07
15	Negus	1299	M. T. S.	17.53	o. s.	65.7	−0.18	+0.00216	+1.23	+1.09	−0.26	−0.17
16	Bruce	581	M. T. S.	18.23	o. s.	66.2	−2.96	+0.00160	−2.17	−2.00	−2.69	−2.66
17	Negus	1317	M. T. S.	18.31	o. s.	66.6	−0.89	+0.00271	+0.66	+0.27	−0.64	−0.29
18	Negus	1764	M.T.B.C.	18.58	o. s.	−34.0	+2.45	−0.00007	+1.70	+1.44	+2.24	+2.29
19	Nardin	1283	M. T. S.	19.00	v. s.	65.4	0.00	+0.00182	+1.39	+1.01	0.00	+0.09
20	Sewill	3247	M. T. S.	19.01	o. s.	62.6	−0.84	+0.00304	+1.20	+0.76	−0.56	−0.41
21	Negus	919	M. T. S.	19.98	o. s.	68.2	+1.09	+0.00342	+2.81	+2.07	+1.33	+1.89
22	Kullberg	1570	M. T. S.	20.37	o. s.	64.1	−0.68	+0.00291	+1.20	+0.91	−0.39	−0.19
23	Pace	214	M. T. S.	21.32	o. s.	62.6	+2.35	+0.00193	+3.36	+3.33	+2.59	+2.53
24	Whyte Thomson	5241	M. T. S.	21.79	o. s.	66.1	+2.44	+0.00258	+3.84	+3.04	+2.31	+2.61
25	Bliss & Creighton	811	M. T. S.	22.52	o. s.	74.2	−1.95	+0.00349	−0.86	−1.49	−1.74	−0.73
26	Crisp	2894	M. T. S.	23.13	o. s.	85.5	−1.54	+0.00187	−1.16	−1.66	−0.94	−0.10
27	Negus	1813	M. T. S.	26.37	o. s.	59.5	+1.21	+0.00189	+2.81	+2.80	+1.59	+1.57
28	Negus	1928	M.T.B.C.	26.84	o. s.	194.8	+3.47	−0.00022	+1.70	+0.79	+0.67	−0.97
29	Negus	1449	M.T.B.C.	30.50	o. s.	66.0	−1.01	+0.00433	+0.89	+0.74	−0.79	−0.51
30	Russell	6065	M. T. S.	31.86	u. s.	78.6	−0.04	−0.00189	+0.90	+0.10	−0.47	−1.21
31	Bliss	2961	M. T. S.	33.92	o. s.	59.5	+0.70	+0.00111	+1.63	+1.41	+0.56	+0.40

M. T. S.=Mean time standard. M. T. B. C.=Mean time break circuit.

Observatory, Washington, D. C., August 3, 1921, to January 9, 1922.

chronometers with trial numbers greater than 35 omitted.]

Mean daily rates.															
Special temperatures.						**Ordinary temperatures.**									
50	50	55	70	85	90	76.7	76.3	74.8	72.6	76.6	77	74.2	73.4	70	63.2
55.8	58	48	43	38	31	70	70.5	71	66	76	71	72.5	70.5	66.3	55
Nov. 21 to 28.	Nov. 28 to Dec. 5.	Dec. 7 to 14.	Dec. 16 to 23.	Dec. 24 to 31.	Jan. 2 to 9.	Aug. 3 to 10.	Aug. 10 to 17.	Aug. 17 to 24.	Aug. 24 to 31.	Aug. 31 to Sep. 7.	Sept. 7 to 14.	Sept. 14 to 21.	Sept. 21 to 28.	Sept. 28 to Oct. 5.	Oct. 5 to 12.
s.	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*
−0. 87	−0. 77	−0. 77	−0. 54	−0. 19	−0. 09	−0. 47	−0. 43	−0. 41	−0. 44	−0. 46	−0. 31	−0. 40	−0. 43	−0. 53	−0. 61
+1. 89	+1. 36	+1. 31	+1. 09	+0. 54	+0. 44	+0. 80	+0. 89	+0. 97	+0. 79	+0. 69	+0. 91	+0. 81	+0. 59	+0. 74	+1. 00
+1. 71	+2. 00	+1. 21	+0. 99	+0. 43	+0. 31	+0. 71	+1. 09	+0. 67	+0. 74	+1. 03	+0. 79	+0. 86	+1. 00	+0. 64	+0. 79
+0. 29	+0. 57	+0. 07	+0. 56	+1. 19	+0. 90	+1. 10	+1. 19	+1. 19	+1. 14	+1. 24	+1. 21	+1. 21	+1. 04	+0. 93	+0. 64
+0. 83	+0. 86	+0. 97	+1. 16	+1. 81	+1. 67	+1. 74	+1. 60	+1. 66	+1. 71	+1. 60	+1. 66	+1. 84	+2. 00	+1. 91	+1. 71
−1. 74	−1. 89	−1. 93	−2. 24	−2. 21	−2. 24	−2. 60	−2. 73	−2. 91	−2. 90	−2. 66	−2. 69	−3. 00	−3. 16	−2. 99	−2. 79
−1. 77	−1. 47	−1. 46	−0. 64	−0. 90	−0. 71	−0. 13	−0. 31	−0. 36	−0. 36	−0. 24	−0. 19	−0. 31	−0. 33	−0. 73	−1. 06
+2. 50	+2. 40	+2. 26	+1. 89	+2. 43	+3. 06	+2. 33	+2. 24	+2. 27	+2. 19	+2. 30	+2. 50	+2. 31	+2. 29	+2. 17	+2. 09
−1. 81	−1. 97	−1. 79	−1. 19	−1. 50	−1. 89	−1. 20	−1. 36	−1. 53	−1. 69	−1. 91	−1. 66	−1. 69	−1. 83	−1. 84	−1. 86
+0. 64	+0. 19	−0. 06	−0. 29	−0. 56	−1. 11	+0. 07	+0. 14	−0. 17	−0. 40	−0. 51	−0. 51	−0. 59	+0. 01	0. 00	−0. 29
−0. 26	+0. 13	−0. 49	−1. 46	−0. 47	−0. 06	−1. 67	−1. 39	−1. 77	−1. 79	−1. 50	−1. 71	−1. 61	−1. 64	−1. 60	−1. 40
−0. 51	−0. 70	−0. 79	−0. 51	+0. 66	+1. 46	−0. 57	−0. 66	−0. 44	−0. 57	−0. 54	−0. 44	−0. 51	−0. 50	−0. 53	−0. 66
+1. 33	+1. 31	+0. 66	−0. 09	+0. 41	+0. 21	−0. 11	+0. 27	+0. 14	+0. 13	+0. 54	+0. 50	+0. 61	+0. 41	+0. 47	+0. 81
−0. 36	−0. 27	−0. 46	−0. 54	−0. 39	−0. 74	−0. 10	−0. 43	−0. 40	−0. 60	−0. 79	−0. 86	−1. 19	−1. 09	−1. 09	−1. 09
+0. 43	+0. 24	+0. 31	−0. 01	+0. 14	+1. 33	−0. 77	−0. 79	−1. 24	−1. 33	−1. 00	−0. 84	−1. 00	−0. 97	−1. 11	−1. 20
−2. 14	−2. 36	−2. 86	−3. 19	−2. 81	−2. 27	−2. 90	−2. 93	−3. 39	−3. 19	−3. 57	−3. 50	−3. 40	−2. 99	−3. 46	−3. 69
−0. 14	−0. 29	−0. 77	−1. 09	−0. 21	+0. 09	+0. 01	−0. 11	−0. 24	−0. 36	−0. 20	−0. 27	−0. 40	−0. 50	−0. 73	−0. 81
+2. 07	+2. 50	+1. 57	+1. 23	+1. 61	+1. 11	−0. 46	−0. 57	−0. 27	−0. 27	−0. 81	−0. 61	−0. 33	−0. 20	−0. 53	−0. 11
+0. 10	+0. 44	+0. 31	+0. 09	+0. 40	+1. 09	+1. 37	+1. 10	+1. 00	+0. 79	+1. 26	+1. 39	+1. 29	+1. 10	+0. 47	+0. 16
−0. 13	−0. 23	−0. 89	−0. 89	+0. 40	+1. 31	+0. 21	+0. 01	−0. 11	−0. 33	−0. 10	+0. 14	+0. 10	−0. 13	−0. 29	−0. 44
+1. 87	+1. 71	+1. 49	+0. 86	+2. 03	+2. 94	+0. 54	+0. 67	+0. 70	+0. 67	+0. 77	+0. 83	+0. 53	+0. 87	+0. 74	+0. 67
0. 00	−0. 17	−0. 70	−0. 76	+0. 27	+0. 96	+0. 17	0. 00	−0. 09	−0. 06	+0. 10	+0. 26	+0. 04	−0. 29	−0. 39	−0. 61
+2. 56	+2. 97	+2. 49	+2. 29	+3. 14	+3. 01	+1. 60	+1. 64	+1. 50	+1. 61	+1. 50	+1. 50	+1. 39	+1. 23	+1. 56	+2. 26
+3. 24	+3. 30	+2. 91	+2. 66	+3. 67	+4. 46	+2. 50	+2. 46	+2. 49	+2. 31	+2. 53	+2. 54	+2. 57	+2. 39	+2. 14	+2. 04
−0. 17	0. 00	−0. 60	−2. 04	−1. 60	−1. 13	−1. 40	−2. 10	−1. 96	−1. 90	−1. 86	−2. 10	−2. 10	−2. 19	−1. 83	−1. 84
+0. 67	+1. 30	+0. 49	−1. 24	−1. 43	−1. 77	−0. 10	−0. 17	+0. 03	+0. 19	−0. 11	+0. 10	+0. 11	+0. 11	0. 00	−0. 10
+1. 16	+0. 71	+0. 93	+1. 24	+2. 09	+1. 90	+0. 44	+0. 41	+0. 26	−0. 13	+0. 24	+0. 33	−0. 04	−0. 26	−0. 37	−0. 49
−1. 30	−1. 31	−0. 76	−0. 63	+0. 81	+0. 61	+1. 27	+1. 00	+0. 96	+0. 69	+0. 97	+0. 96	+0. 74	+0. 50	+0. 11	−0. 16
+0. 21	+0. 27	−0. 47	−1. 10	+0. 37	+1. 10	−0. 20	−0. 20	−0. 20	−0. 21	−0. 33	+0. 21	−0. 14	−0. 50	−0. 71	−0. 86
−1. 29	−1. 69	−0. 97	+0. 11	−0. 33	+0. 21	−1. 11	−1. 17	−1. 26	−1. 27	−1. 79	−1. 90	−1. 71	−1. 81	−2. 06	−2. 01
+0. 83	+0. 97	+1. 03	+1. 09	+1. 43	+0. 54	+2. 80	+2. 74	+2. 59	+2. 46	+3. 19	+3. 31	+3. 26	+2. 96	+2. 21	+1. 56

TABLE VIII.—*Data of trial of old and new watches at the United States*

[The signs are astronomical, + losing, − gaining. Data of new watches with trial num-

									Mean daily rates.			
									Special temperatures.			
Temperature.........degrees F..									90	85	70	55
Relative humidity by sling psychrometer.........per cent..									35	39.5	46	50
Order of merit.	Balance: o=ordinary. v=invar. Hairspring: p=palladium. s=steel.			Trial number.	Balance, hairspring.	Point of compensation.			Oct. 15 to 22.	Oct. 24 to 31.	Nov. 2 to 9.	Nov. 12 to 19.
	Watches.		Kind.			Temperature.	Rate.	Temperature constant.				
	New.											
						°	s	s	s	s	s	s
1	Vacheron and Constantin...	361624	T. B. W.	2.49	v. s.	72.2	+0.38	−0.00038	+0.20	+0.20	+0.29	+0.23
2	.....do..........	374604	T. B. W.	7.54	v. s.	167.8	−1.39	+0.00007	−0.73	−0.99	−0.73	−0.50
3	.....do..........	379510	T. B. W.	16.66	v. s.	73.7	−1.09	−0.00209	−1.14	−1.01	−1.04	−2.04
	Old.											
1	Longines.......	2517934	T. B. W.	15.77	v. s.	62.5	−2.34	+0.00173	....	−1.33	−2.21	−2.13
2	Patek Philippe.	170291	T. B. W.	17.52	v. s.	34.4	−3.15	+0.00036	−1.86	−2.39	−2.66	−3.26
3	Longines.......	2965531	T. B. W.	23.78	v. s.	74.0	−0.41	−0.00231	−1.21	−0.83	−0.41	−1.40
4	Ditisheim......	24585	T. B. W.	32.39	v. s.	52.3	+0.40	−0.00076	−0.34	−0.54	+0.07	0.00

T. B. W.=Torpedo boat watch.

TABLE IX.—*Data of trial of old watches at the United States Naval*

[The signs are astronomical, + losing, − gaining. Data of

									Mean daily rates.			
									Special temperatures.			
Temperature.........degrees F..									90	85	70	55
Relative humidity by sling psychrometer.........per cent..									35	39.5	46	50
Order of merit.	Balance: o=ordinary. v=invar. Hairspring: p=palladium. s=steel.			Trial number.	Balance, hairspring.	Point of compensation.			Oct. 15 to 22.	Oct. 24 to 31.	Nov. 2 to 9.	Nov. 12 to 19.
	Watch.		Kind.			Temperature.	Rate.	Temperature constant.				
						°	s	s	s	s	s	s
1	Longines......	2965524	T. B. W.	10.27	v. s.	47.5	+2.18	−0.00036	+1.84	+1.46	+1.80	+2.07
2	.....do.........	2965527	T. B. W.	20.32	v. s.	57.8	+4.38	+0.00042	+3.96	+4.49	+4.19	+4.21
3	.....do.........	2511714	T. B. W.	28.87	v. s.	94.1	−1.75	+0.00084	−2.07	−1.81	−1.30	−0.46
4	Hamilton......	Ⓝ5128	P. B. W.	33.37	v. s.	76.9	+0.44	+0.00331	+0.59	+0.54	+0.64	+1.96

T. B. W.=Torpedo boat watch. P. B. W.=Patrol boat watch.

Naval Observatory, Washington, D. C., October 15, 1921, to March 27, 1922.

bers greater than 25 omitted; data of old watches with trial numbers greater than 35 omitted.]

Mean daily rates.															
Special temperatures.						Ordinary temperatures.									
50	50	55	70	85	90	65	58.2	63.5	64	59.1	63.5	62.1	62.9	62.9	59.6
55.8	58	48	43	38	31	......	......	......	......	......	......	......	......	......	......
Nov. 21 to 28.	Nov. 28 to Dec. 5.	Dec. 7 to 14.	Dec. 16 to 23.	Dec. 24 to 31.	Jan. 2 to 9.	Jan. 16 to 23.	Jan. 23 to 30.	Jan. 30 to Feb. 6.	Feb. 6 to 13.	Feb. 13 to 20.	Feb. 20 to 27.	Feb. 27 to Mar. 6.	Mar. 6 to 13.	Mar. 13 to 20.	Mar. 20 to 27.
s	s	s	s	s	s	s	s	s	s	s	s	s	s	s	s
+0.21	+0.23	+0.31	+0.46	+0.43	+0.41	+0.41	+0.27	+0.27	+0.33	+0.43	+0.47	+0.44	+0.60	+0.66	+0.51
−0.10	−0.33	−0.57	−0.77	−0.87	−1.33	−1.43	−1.39	−1.31	−1.33	−1.54	−1.29	−1.09	−0.94	−0.93	−1.10
−1.64	−1.70	−1.61	−1.19	−1.71	−1.69	−1.76	−1.90	−1.89	−1.74	−1.83	−1.59	−1.71	−1.71	−1.84	−1.71
−1.50	−1.70	−2.34	−2.27	−1.59	−1.86	−3.14	−3.33	−3.36	−3.21	−3.11	−3.19	−3.03	−3.10	−2.86	−2.51
−2.79	−2.87	−2.74	−2.74	−2.09	−1.46	−2.21	−1.86	−2.14	−2.09	−2.49	−2.80	−2.59	−2.23	−2.03	−2.83
−0.97	−0.91	−1.07	−0.46	−0.54	−1.10	−0.76	−0.67	−1.13	−0.96	−1.09	−1.21	−1.24	−1.40	−1.19	−1.63
+0.70	+0.97	+0.79	+0.26	−0.30	−0.11	−0.49	−0.09	+0.44	+0.10	−0.39	+0.26	+1.09	+0.61	+0.26	+0.24

Observatory, Washington, D. C., August 3, 1921, to January 9, 1922.

watches with trial number greater than 35 omitted.]

Mean daily rates.															
Special temperatures.						Ordinary temperatures.									
50	50	55	70	85	90	76.7	76.3	74.8	72.6	76.6	77	74.2	73.4	70	63.2
55.8	58	48	43	38	31	70	70.5	71	66	76	71	72.5	70.5	66.3	55
Nov. 21 to 28.	Nov. 28 to Dec. 5.	Dec. 7 to 14.	Dec. 16 to 23.	Dec. 24 to 31.	Jan. 2 to 9.	Aug. 3 to 10.	Aug. 10 to 17.	Aug. 17 to 24.	Aug. 24 to 31.	Aug. 31 to Sept. 7.	Sept. 7 to 14.	Sept. 14 to 21.	Sept. 21 to 28.	Sept. 28 to Oct. 5.	Oct. 5 to 12.
s.	s.	s	s	s	s	s	s	s	s	s	s	s	s	s	s
+2.61	+2.49	+2.24	+2.19	+1.90	+0.83	+2.93	+2.53	+2.84	+2.54	+2.77	+2.73	+2.74	+2.73	+2.80	+2.81
+4.46	+4.36	+4.56	+4.69	+4.89	+4.46	+2.91	+2.81	+3.20	+3.61	+3.44	+3.31	+3.47	+3.57	+3.79	+3.64
−0.16	+0.03	−0.47	−1.23	−1.54	−2.43	−0.37	−0.19	−0.59	+0.14	+0.16	+0.63	+0.64	+0.54	+0.71	+0.04
+2.99	+2.91	+2.10	+0.57	+0.77	+1.61	+1.74	+1.64	+1.46	+1.66	+1.43	+1.63	+1.80	+1.06	+0.90	+1.40

TABLE X.—*Data of trial of new chronometers at the United States Naval Observatory, Washington, D. C., January 19, 1922, to June 26, 1922.*

[The signs are astronomical, +losing; − gaining. Data of chronometers with trial numbers greater than 25 omitted.]

									Mean daily rates.			
									Special temperatures.			
Temperature......degrees F..									90	85	70	55
Relative humidity by sling psychrometer......per cent..									22.5	29	35	47
Order of merit.	Balance: o=ordinary. v=invar. Hairspring: p=palladium. s=steel. Chronometer.		Kind.	Trial number.	Balance, hairspring.	Point of compensation. Temperature.	Rate.	Temperature constant.	Jan. 19 to 26.	Jan. 28 to Feb. 4.	Feb. 6 to 13.	Feb. 15 to 22.
						°	s.	s.	s.	s.	s.	s.
1	Nardin..........	1654	M. T. S.	5.91	v. s.	43.3	−2.11	+0.00040	−0.93	−1.51	−1.90	−2.06
2	Nardin..........	1641	M. T. S.	5.92	v. s.	54.2	+0.90	+0.00040	+1.01	+1.09	+0.90	+0.93
3	Nardin..........	1667	M. T. S.	9.97	v. s.	137.5	−0.71	−0.00016	−0.80	−1.19	−1.14	−1.64
4	Lange..........	521	M. T. S.	10.29	v. s.	22.0	−0.35	−0.00022	−0.74	−0.96	−0.88	−0.61
5	Nardin..........	1661	M. T. S.	11.20	v. s.	71.3	−0.28	−0.00038	−0.39	−0.31	−0.24	−0.44
6	Kurtz..........	133	M. T. S.	12.58	v. s.	273.1	−1.64	+0.00002	−0.24	−0.54	−0.60	−0.69
7	Nardin..........	1621	M. T. S.	12.80	v. s.	65.7	−0.08	+0.00073	+0.37	+0.14	−0.04	+0.13
8	Kurtz..........	138	M. T. S.	13.68	v. s.	7.4	−0.90	+0.00027	+0.83	+0.71	+0.13	−0.31
9	Nardin..........	1611	M. T. S.	14.05	v. s.	103.9	−2.66	+0.00038	−1.96	−2.44	−2.23	−1.49
10	Kurtz..........	135	M. T. S.	16.41	v. s.	86.4	−1.74	+0.00104	−1.54	−1.96	−1.96	−0.91
11	Nardin..........	1599	M. T. S.	20.51	v. s.	57.5	−0.62	+0.00040	−0.64	−0.70	−0.69	−0.69
12	Lange..........	522	M. T. S.	20.93	v. s.	51.1	−1.55	−0.00064	−1.60	−1.79	−1.51	−1.47
13	Nardin..........	1622	M. T. S.	22.36	v. s.	80.8	−1.50	+0.00051	−0.96	−1.49	−1.50	−1.29
14	Kurtz..........	136	M. T. S.	23.80	v. s.	81.0	+1.60	−0.00096	+1.61	+1.46	+1.49	+0.90

M. T. S=Mean time standard.

TABLE XI.—*Data of trial of new watches at the United States Naval*

[The signs are astronomical, + losing; − gaining. Data of

									Mean daily rates.			
									Special temperatures.			
Temperature......degrees F..									90	85	70	55
Relative humidity by sling psychrometer......per cent..									22.5	29	35	47
Order of merit.	Balance: o=ordinary. v=invar. Hairspring: p=palladium. s=steel. Watch.		Kind.	Trial number.	Balance, hairspring.	Point of compensation. Temperature.	Rate.	Temperature constant.	Jan. 19 to 26.	Jan. 28 to Feb. 4.	Feb. 6 to 13.	Feb. 15 to 22.
						°	s.	s.	s.	s.	s.	s.
1	Longines.......	2965537	T. B. W.	6.69	v. s.	66.2	−0.81	−0.00133	−1.04	−1.07	−0.80	−0.89
2	Longines.......	1927924	T. B. W.	11.71	v. s.	73.5	−0.93	+0.00067	−0.47	−0.81	−1.06	−0.79
3	Longines.......	2965514	T. B. W.	12.97	v. s.	65.0	+0.03	−0.00213	−1.59	−0.87	−0.03	−0.31
4	Longines.......	2517919	T. B. W.	17.82	v. s.	−14.1	−4.40	+0.00022	−1.67	−1.97	−3.00	−3.67
5	Longines.......	2517936	T. B. W.	18.06	v. s.	64.1	+0.47	+0.00082	+1.13	+1.06	+0.83	+0.93
6	Longines.......	2511720	T. B. W.	18.15	v. s.	57.5	+2.34	+0.00053	+3.27	+3.16	+2.59	+2.40
7	Longines.......	2517938	T. B. W.	18.28	v. s.	−95.0	+2.92	+0.00013	+2.24	+1.77	+0.99	+0.06
8	Longines.......	2965526	T. B. W.	20.78	v. s.	70.0	+2.46	−0.00071	+2.06	+2.17	+2.41	+2.11
9	Nardin.........	21964	T. B. W.	21.89	v. s.	87.5	+1.18	+0.00027	+0.94	+1.00	+0.93	+1.16
10	Longines.......	2059715	T. B. W.	22.49	v. s.	57.4	−0.23	+0.00091	+0.40	+0.13	−0.27	−0.54

T. B. W.=Torpedo-boat watch.

Table X.—*Data of trial of new chronometers at the United States Naval Observatory, Washington, D. C., January 19, 1922, to June 26, 1922.*

[The signs are astronomical, + losing; − gaining. Data of chronometers with trial numbers greater than 25 omitted.]

Mean daily rates.															
Special temperatures.						Ordinary temperatures.									
50	50	55	70	85	90	70.5	64.6	67.3	70.5	70.2	71	70.7	74.0	75.2	74.8
38.5	56	......	48	......	......	......	......	......	......	......	......	......	......	......	......
Feb. 24 to Mar. 3.	Mar. 3 to 11.	Mar. 13 to 20.	Mar. 22 to 29.	Mar. 31 to Apr. 7.	Apr. 9 to 17.	Apr. 17 to 24.	Apr. 24 to May 1.	May 1 to 8.	May 8 to 15.	May 15 to 22.	May 22 to 29.	May 29 to June 5.	June 5 to 12.	June 12 to 19.	June 19 to 26.
s.	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*
−1.96	−2.14	−2.06	−1.76	−1.33	−1.26	−1.94	−1.77	−2.00	−2.01	−2.16	−2.11	−1.96	−1.96	−1.63	−1.77
+0.96	+0.86	+0.87	+1.11	+1.47	+1.46	+1.60	+1.60	+1.31	+1.50	+1.57	+1.74	+1.76	+1.71	+1.86	+1.89
−1.54	−1.71	−1.90	−1.69	−1.10	−0.70	−1.13	−1.33	−1.46	−1.16	−1.36	−1.13	−0.97	−0.91	−0.90	−0.67
−0.39	−0.39	−0.57	−0.90	−1.50	−1.79	−1.50	−1.33	−1.26	−1.20	−1.11	−1.04	−1.06	−1.10	−1.20	−1.20
−0.29	−0.25	−0.31	−0.31	−0.39	−0.48	−0.39	−0.24	−0.24	−0.11	−0.01	+0.13	+0.37	+0.50	+0.44	+0.53
−0.44	−0.46	−0.49	−0.86	−1.17	−1.34	−1.19	−0.96	−1.03	−1.19	−1.17	−1.00	−0.93	−0.61	−0.64	−0.74
+0.11	−0.10	−0.14	−0.10	+0.24	+0.43	0.00	+0.01	−0.30	−0.14	−0.09	+0.11	−0.16	+0.56	−0.80	+0.06
−0.53	−0.58	−0.30	+0.16	+0.69	+0.63	+0.10	−0.16	+0.06	+0.33	+0.41	+0.47	+0.61	+0.83	+1.00	+1.10
−1.96	−1.89	−2.00	−2.21	−2.59	−2.71	−2.16	−2.09	−2.21	−2.27	−2.14	−2.23	−2.64	−2.93	−2.86	−2.47
−0.73	−0.64	−0.51	−0.97	−1.53	−2.00	−1.56	−1.23	−1.26	−1.31	−1.39	−1.39	−1.37	−1.50	−1.66	−1.69
−0.57	−0.48	−0.54	−0.44	+0.06	+0.36	+0.14	+0.03	−0.03	+0.01	−0.10	+0.07	+0.29	+0.43	+0.91	+1.03
−1.47	−1.51	−1.66	−2.06	−2.79	−3.25	−2.89	−2.79	−2.83	−2.79	−2.79	−2.73	−2.67	−2.71	−2.69	−2.63
−0.77	−0.81	−1.04	−1.39	−1.49	−1.58	−1.34	−1.29	−1.16	−1.00	−1.16	−0.90	−0.54	−0.46	−0.24	−0.24
+0.97	+0.81	+1.00	+1.47	+1.69	+1.48	+1.03	+0.83	+1.13	+1.00	+1.06	+1.06	−0.13	+0.24	+0.33	+0.91

Observatory, Washington, D. C., January 19, 1922, to June 26, 1922.

watches with trial numbers greater than 25 omitted.]

Mean daily rates.															
Special temperatures.						Ordinary temperatures.									
50	50	55	70	85	90	70.5	64.6	67.3	70.5	70.2	71	70.7	74	75.2	74.8
38.5	56	......	48	......	......	......	......	......	......	......	......	......	......	......	......
Feb. 24 to Mar. 3.	Mar. 3 to 11.	Mar. 13 to 20.	Mar. 22 to 29.	Mar. 31 to Apr. 7.	Apr. 9 to 17.	Apr. 17 to 24.	Apr. 24 to May 1.	May 1 to 8.	May 8 to 15.	May 15 to 22.	May 22 to 29.	May 29 to June 5.	June 5 to 12.	June 12 to 19.	June 19 to 26.
s.	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*
−1.10	−1.20	−1.07	−0.86	−1.49	−1.61	−1.89	−1.76	−1.79	−1.80	−1.81	−1.63	−1.57	−1.93	−1.83	−1.79
−0.60	−0.62	−0.61	−0.77	−0.87	−0.92	−0.97	−0.69	−0.93	−1.00	−1.03	−0.96	−0.70	−0.41	−0.44	−0.10
−0.47	−0.30	−0.04	−0.07	−0.76	−1.19	−0.73	−0.54	−0.57	−0.69	−0.60	−0.47	−0.39	−0.50	−0.37	−0.17
−3.60	−3.44	−3.00	−2.66	−2.47	−2.90	−3.24	−3.20	−3.49	−3.51	−3.70	−3.51	−3.39	−3.29	−3.19	−3.24
+1.13	+0.39	+0.16	+0.17	+0.60	+0.29	+0.21	+0.31	+0.19	+0.11	+0.19	+0.70	+0.66	+0.64	+0.50	+0.33
+2.56	+2.21	+2.29	+2.24	+2.33	+2.15	+1.31	+1.37	+1.39	+1.53	+1.60	+1.84	+2.06	+2.23	+1.89	+1.76
−0.33	−0.34	+0.11	+0.43	+1.04	+0.78	+0.47	+0.14	+0.10	+0.36	+0.46	+0.30	+0.39	+0.43	+0.26	+0.36
+2.26	+2.48	+2.50	+2.50	+2.44	+2.08	+1.89	+1.83	+2.07	+2.39	+2.70	+2.80	+2.71	+2.57	+1.69	+1.64
+1.84	+1.96	+1.76	+1.60	+1.37	+1.35	+1.16	+0.56	+0.63	+0.97	+1.30	+1.31	+1.29	+1.37	+1.26	+1.69
−0.43	−0.26	+0.10	+0.11	+0.81	+0.60	−0.04	−0.14	−0.61	−0.53	+0.07	+0.46	+0.23	−0.50	−0.09	−0.14

APPENDIX NO. 2 TO THE ANNUAL REPORT OF THE
CHIEF OF THE BUREAU OF NAVIGATION, 1926

ANNUAL REPORT OF THE

NAVAL OBSERVATORY

FOR THE

FISCAL YEAR 1926

WASHINGTON
GOVERNMENT PRINTING OFFICE
1926

APPENDIX NO. 2

REPORT OF SUPERINTENDENT OF NAVAL OBSERVATORY

NAVY DEPARTMENT,
UNITED STATES NAVAL OBSERVATORY,
Washington, D. C., July 1, 1926.

From: Superintendent, Naval Observatory.
To: Chief of Bureau of Navigation.
Subject: Report of the Superintendent, Naval Observatory, for the fiscal year ending June 30, 1926.

Capt. Edwin T. Pollock, United States Navy, continued as superintendent.

The astronomical council, composed of the superintendent, the assistant superintendent, and six astronomers, was unchanged and continued its usual work.

The Naval Observatory continued to supply the Navy, the merchant marine, and the country with the astronomical data required by navigators, surveyors, astronomers and other scientists, and with the "time" so essential to them and to all commercial activities.

The regular and also special time signals during the summer of 1925 were of great use to the United States Coast and Geodetic Survey for longitude work in the western Aleutian Islands; to the Canadian Government for similar work in their great northwest where they had 25 surveying parties in the field. The Swiss Commission determining the boundary between Colombia and Venezuela used the signals for two years until their work was finished in 1925, and the signals have been widely used in other countries, as far away as Australia and New Zealand, as well as over the Atlantic and Pacific Oceans.

Since July, 1925, the Naval Observatory time signals have been transmitted via the Western Union Telegraph Co.'s wires to all parts of the United States. Theretofore the signals from the chronometer and time station at Mare Island had been furnishing the time for the west coast.

A new use for the time signals is in gravity determinations which are used in locating oil deposits and for other purposes.

A Dutch submarine will use them in gravity determinations at sea while en route from Holland to Java via the Panama Canal.

The accuracy of the signals is such that the corrections are calculated to the thousandth of a second and the list of these corrections is sent monthly to over 50 parties who desire them.

The department of material has continued to furnish the Navy with navigational instruments, some of which have been greatly improved, both for surface and aircraft. Some of these were used in Lieutenant Commander Byrd's flight to the North Pole.

The nautical instrument repair shop continues to be efficient in saving time and money on repairs to navigational and surveying instruments.

Over 2,100 visitors, including schools, had a look through the observatory telescopes.

Twelve officers took the compass course and seven officers were given instruction preliminary to going on surveying duty under the Hydrographic Office.

The plans for the international "round-the-world" longitude determination to begin October 1, 1926, have been completed.

The total solar eclipse of January 14, 1926, was successfully observed in Sumatra by a party consisting of Capt. F. B. Littell (Math.), United States Navy, Associate Astronomer G. H. Peters, and Assistant Astronomer G. M. Raynsford, of the Naval Observatory, and Prof. John A. Anderson, of Mount Wilson Observatory. Lieut. H. C. Kellers (M. C.), United States Navy, who accompanied the party as medical officer, collected over 9,000 specimens for the Smithsonian Institution in addition to his other duties. The party left the Naval Observatory on August 21, 1925, and returned on April 7, 1926.

The superintendent, as delegate from the Navy Department, and as a member of the International Astronomical Union Commissions on "time" and "longitude," attended the triennial meeting of the union at Cambridge, England, in July, 1925, with very satisfactory results. At that meeting the accuracy of the star positions as given in the tables prepared at the Naval Observatory was recognized, in that the union recommended that these positions be used by all astronomers throughout the world.

Contributions on astronomical subjects by members of the observatory staff are enumerated further on.

As a part of the naval exhibit at the Sesquicentennial Exposition at Philadelphia, the Naval Observatory has, besides a complete gyrocompass equipment, historic chronometers and other instruments and various medals awarded members of the staff, etc., a complete working "time service."

Publications in press, etc.:

Volume X, Part I, Naval Observatory Publications, second series (prime vertical volume), will be ready for distribution in August.

Volume XI, Naval Observatory Publications, second series (6-inch transit circle volume), is in the hands of the printer.

The manuscript for the equatorial volume is well toward completion.

The Naval Observatory, Monograph 39, by G. A. Weber, Institute for Government Research, printed April, 1926, gives an excellent history of the Naval Observatory and its organization and activities.

The work of the Naval Observatory and of the superintendent was recognized when the latter was awarded the honorary degree of doctor of science at Wittenberg College, Springfield, Ohio, on June 10, 1926.

During March, 1926, it was necessary to close permanently the road to Wisconsin Avenue, as the traffic interfered with the efficient working of certain instruments.

DEPARTMENT OF MATERIAL

Capt. W. C. Asserson, United States Navy, continued as assistant to the superintendent, head of the department, and supply officer.

On his detachment, February 15, 1926, Chief Gunner John Brenner, United States Navy, was relieved as assistant to the officer in charge of the aeronautical instrument division by Chief Aerographer Franklin G. Williams, United States Navy, who had reported for duty on February 10, 1926.

Lieut. Commander J. F. Crowell, United States Navy, remained in charge of the nautical instrument division and the time service until his detachment on December 1, 1925. Commander A. G. Stirling, United States Navy, took up the foregoing duties on his reporting for duty on December 21, 1925.

Lieut. J. Meyer, United States Navy, was relieved as assistant in the gyrocompass division when detached on April 28, 1926, by Chief Electrician C. H. Snovel, United States Navy, who had reported for duty on February 24, 1926.

INSPECTION SERVICE UNDER NAVAL OBSERVATORY

[Lieut. Commander W. B. Phillips, United States Navy, in charge]

Lieut. R. C. Bartmann, United States Navy, reported for duty to the inspector of navigational material, New York, in the early part of June, 1926.

On his detachment in March, 1926, Chief Electrician H. C. Woodward, United States Navy, was relieved as assistant to the inspector by Gunner H. S. Raber, United States Navy, who reported for duty early in April, 1926.

The specific activities of the several divisions of the department are described in the following pages in more detail.

GYROCOMPASS DIVISION

[Lieut. Commander W. D. Chandler, jr., United States Navy, in charge]

New installations.—Sperry Mark VIII, Model 1, gyrocompass equipments were assigned to 31 destroyers and 4 light mine layers and their installation directed.

Sperry Mark VIII, Model 1, gyrocompass equipments were assigned to and installed on the U. S. S. *V-1*, *V-2*, and *V-3*.

A Sperry Mark VIII, Model 1, gyrocompass equipment was placed in the Navy exhibit at the Sesquicentennial Exposition at Philadelphia.

An Arma Mark II gyrocompass equipment was assigned to and installed on the U. S. S. *Wood*.

Old equipments (*salvaged*).—One salvaged equipment (Sperry type) which had been modified to the mercury ballistic type was assigned to and installed on the U. S. S. *Bushnell*.

Modernization.—The project of modification of the Sperry Mark I and Mark II gyrocompasses to the mercury ballistic type by the navy yards at Norfolk and Puget Sound was continued. Twenty-four such compasses were assigned to vessels of the Navy to replace compasses of the older type.

Repair and upkeep facilities.—The *Altair*, *Black Hawk*, *Dobbin*, an *Whitney* were supplied with equipment for their gyrocompass repa shops to improve the facilities of these tenders to care for the gyr compass equipments of vessels of the squadrons to which they a assigned as tenders.

New material.—Contracts for new gyrocompass equipments an gyrocompass material have been made as follows:

Contract No.	Manufacturer	Material
65971	Arma	Duplex equipment for U. S. S. Texas.
66871	Sperry	Duplex equipment for U. S. S. New York.
67233	do	Repair shop material for gyrocompass repair shops.
67270	Arma	Do.
67096	do	Dead reckoning tracer equipments for U. S. S. New York an Texas.

Deliveries—New equipments.—The Sperry Gyroscope Co. completed delivery of the 50 Mark VIII, Model 1, equipments due o contracts 60627 and 60812, and, in addition, delivered 5 such equipments due under contract 63836.

These equipments have been assigned to vessels for installation as rapidly as they have passed the acceptance tests.

New developments.—During August, 1925, certain tests of gyrocompasses were conducted on the U. S. S. *Brooks* in the way of investigation of the "turning error" and looking toward means for its elimination.

Work was commenced during the year on the manufacture of dead reckoning tracer equipments by the Arma Engineering Co. Four such equipments are being manufactured for the U. S. S. *Texas*, *New York*, *Lexington*, and *Saratoga*. It is expected these equipments will be a great improvement over the equipments at present in service.

MAGNETIC COMPASS DIVISION

[Commander William H. Lee, United States Navy, in charge]

The routine review of annual compass reports from vessels in commission has been completed. The results indicate a slight increase of interest on the part of navigating officers toward the importance of the magnetic compass. This interest is reflected in the increased number of officers taking the compass course. During the fiscal year 12 officers took this course.

The increasing efficiency and reliability of the gyrocompass has created a tendency among navigating officers to neglect the magnetic compass. In this connection it is desired to emphasize the fact that a careful navigator will at all times have a well compensated and thoroughly understood magnetic compass at his command.

To meet the demand for a compensating boat binnacle and compass, experiments were conducted with the No. 3 binnacle and 5-inch compass. These experiments were a decided success, and to make them available for issue, the entire stock of these instruments is being reconditioned and fitted with new cards. This work is being performed by the navy yards at Norfolk and Mare Island. When these compasses are ready for distribution it is the intention to change the allowance lists of vessels to provide one compensating boat binnacle and compass for each power boat on board. It will be necessary during the next fiscal year to purchase more compasses of this type to equip the active vessels of the fleet.

During the year experiments were conducted to develop a more efficient instrument for taking bearings from the gyrocompass repeater. Following the model of the old azimuth circle an instrument was designed for the purpose of taking terrestrial bearings only. This instrument is more sturdy and less easily thrown out of adjustment than the azimuth circle. It shows a much larger segment of the repeater card and is adapted to facilitate the taking of relative bearings. Fifty of these instruments were distributed to the fleet and the enthusiastic reports which have been received from individual vessels indicate that they have met a real demand. A contract has been let for 400 of them and the allowance lists of vessels have been changed to provide two for each vessel fitted with a gyrocompass.

Experiments are being continued with these instruments to fit them with a satisfactory telescope.

The nautical instrument repair shop has been constantly engaged to the limits of its capacity in the repair of damaged magnetic compasses, azimuth circles, and other instruments.

AERONAUTICAL AND AEROLOGICAL INSTRUMENT SECTION

[Commander William H. Lee, United States Navy, in charge]

The Naval Observatory has continued to conduct experiments and correspondence in regard to the design, procurement, development, and issue of aeronautical and aerological instruments.

The development of the earth inductor compass has progressed satisfactorily but there are still many mechanical difficulties to be overcome before it may be said to be entirely reliable.

Continued experiments with various types of magnetic compasses for aircraft are beginning to crystallize service opinion upon the requirements in this respect with reference both to the magnetic and the physical qualities of these instruments. The modification of the NS II compass has been a decided success from almost every point of view and it is the intention eventually to modify the entire stock of these compasses. When this is finally done, there will be on hand about 2,000 first-class aircraft compasses, disregarding other types altogether.

The duralumin octant designed by the observatory and fitted with the Willson bubble telescope has marked a decided advance in the development of an instrument suitable for measuring the altitude of heavenly bodies from aircraft.

This instrument was designed by the observatory and manufactured by the Messrs. Brandis & Sons. The manufacturers have provided an excellent instrument and have interested themselves in the further development of the Willson bubble telescope with the result that a greatly improved instrument is now available. These telescopes have also been adapted to the standard surveying sextant for general shipboard use when the horizon is not visible.

The adaptation of Mr. Littlehales's method of laying down a Sumner line, which was recommended by this office last year, has been tried and is considered to be the best method now available for the accomplishment of this object. In the meanwhile another method which will not require a special set of charts has been proposed by Commander M. R. Pierce, United States Navy, and this office is awaiting the publication of the tables required for its use in order to decide which method will be considered the more suitable.

The Le Prieur navigraph has been tried and a very favorable impression has been made by this instrument. It has limitations due to the difficulty of installing it in certain types of aircraft, especially seaplanes, but an effort is being made to overcome this difficulty. It is expected that this instrument or some adaptation of it will eventually solve the problem of ascertaining the drift and ground speed.

Other instruments, methods of mounting compasses, improved methods of compensating aircraft compasses, and other subjects appertaining to the navigation of the air have been a subject of constant study and experiment by this office. It is hoped, in cooperation with the Bureau of Aeronautics, eventually to standardize navigational instruments, installations, and methods for the different types of aircraft.

The Naval Observatory has continued the supply and upkeep of aerological instruments both ashore and afloat.

The observatory has kept in touch with our naval attachés in order to obtain for the naval air service the latest and best types of aeronautical instruments available throughout the world.

DIVISION OF NAUTICAL INSTRUMENTS AND TIME SERVICE

Commander A. G. Stirling, United States Navy, in charge. Associate Astronomer Paul Sollenberger, technical assistant]

The division has continued its work with reference to nautical instruments and navigational equipment in same manner as reported last year. Reconditioning of Navy standard six-power binoculars has been in progress at the optical shop, navy yard, Washington, D. C., with deliveries at the rate of 50 per month since February, 1926. Plans call for reconditioning about 1,000 glasses. A contract has been entered into with Zeiss & Co. to furnish 532 7 by 50 power prismatic binoculars. These binoculars will be delivered within the next few months and distributed to ships in commission. Ten Navy standard surveying sextants are being fitted with bubble telescopes similar to those used in aviation. When completed these sextants will be issued to ships for trial in observing celestial bodies when the horizon is not visible. The observatory has made considerable effort this past year to impress the service with the necessity of cleaning all chronometers, patrol-boat chronometers, torpedo and patrol-boat watches at least every four years. It is hoped to make the replacement of these instruments requiring cleaning automatic and thus avoid unnecessary correspondence.

An officer from the observatory during the past year inspected navigational material in store at the navy yards, Portsmouth, New York, Philadelphia, Boston; naval supply base, Brooklyn; and submarine base, New London. The following recommendations were made: (1) Inspection of stock at each yard or base quarterly by a line officer attached to the station, (2) repair of material as required with a monthly appropriation under "Instruments and Supplies" for this purpose, (3) minor repairs and cleaning of stock to be effected by the instrument shops at the various yards, (4) sale of obsolete material.

Time service.—Time signals were sent out by the Naval Observatory as shown in the following table. The radio stations listed are operated automatically from the Naval Observatory by telegraphic control lines. In addition to the radio service listed below the noon signals, and to some extent those at 10 p. m., seventy-fifth meridian time, were distributed by the Western Union and Postal Telegraph Cos. to all parts of the United States. A number of privately owned broadcasting stations not shown in the accompanying table automatically repeated the Naval Observatory time signals, either by means of telegraphic control lines or by reradiation. All the radio stations listed are property of the United States Navy, excepting WQL, which belongs to the Radio Corporation of America.

[K. C.=frequency in kilocycles; W. L.=wave length in meters; C. W.=continuous waves; Mod.=modulated waves; G. C. T.=Greenwich civil time; 75 M=seventy-fifth meridian time]

Call	Location	K. C.	W. L.	Kind	Signals ending at—		Dates
					G. C. T.	75 M.	
NAA	Arlington, Va.	113	2,650	Mod.	3 hours	10 p. m.	Throughout year, except Dec. 5, 1925.
		30.6	9,810	C. W.	17 hours	Noon	Throughout year.
					3 hours	10 p. m.	When NSS did not send.
					17 hours	Noon	Do.
		690	435	Mod.	3 hours	10 p. m.	Feb. 3 to June 30, 1926.
					17 hours	Noon	Do.
NSS	Annapolis, Md.	17.5	17,145	C. W.	3 hours	10 p. m.	(1).
					8 hours	3 a. m.	During July, August and September, 1925.
					17 hours	Noon	(1).
NPL	San Diego, Calif.	30.6	9,810	C. W.	do	do	Beginning in July, 1925, and to June 30, 1926. Sundays and holidays excepted.
		100	3,000	Mod.	do	do	Beginning in July, 1925, and to Apr. 14, 1926, Sundays and holidays excepted.
		102	2,940	Mod.	do	do	Apr. 15 to June 30, 1926, Sundays and holidays excepted.
NAR	Key West, Fla.	205	1,460	Mod.	do	do	July 1, 1925, to Apr. 14, 1926, inclusive, Sundays and holidays excepted.
		102	2,940	Mod.	do	do	Apr. 15 to June 30, 1926, inclusive.
NKF	Bellevue, D. C.	4,205	71.3	C. W.	11 hours, 10 minutes.	6.10 a. m.	During September, 1925.
WQL	Coram Hill, Long Island.	17.1	17,500	C. W.	3 hours	10 p. m.	Oct. 12 to Nov. 17, 1925, inclusive.

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[1] Annapolis sent only a few signals from Oct. 1 to Nov. 15, 1925. It did not send from Feb. 1 to Feb. 18, 1926, and on a few other dates. During remainder of year Annapolis sent noon and 10 p. m. signals continuously.

The signals sent via Annapolis at 3 a. m., seventy-fifth-meridian time, were for the use of surveying parties in the United States and Canada. The signals via Bellevue were sent experimentally to determine the utility of high frequency, particularly for reception in the Far East, and the results were very gratifying. Astronomers in Australia and New Zealand reported this frequency to be easily received.

Beginning during the month of July, 1925, the Western Union Telegraph Co. discontinued its former practice of distributing throughout the Pacific coast territory the time signals originating at the United States naval time and chronometer station, Mare Island, Calif. Instead the noon signal from the Naval Observatory is now transmitted over nearly all of the United States. This change has made possible the operation of the naval radio station at San Diego directly from Washington, as has been noted above. Owing to the length of the telegraphic control line, the signal emitted from San Diego lags almost exactly one-half second behind the signal as it leaves the Naval Observatory.

During the months of July, August, and September, 1925, records were made at the Naval Observatory of special time signals sent on continuous waves, frequency 30.6 kilocycles, wave length 9,810 meters, via the naval radio station at San Diego, Calif. These records enabled the Naval Observatory to compute accurate times of these signals for the use of the United States Coast and Geodetic Survey in connection with surveying work in the Aleutian Islands. Owing to atmospheric interferences and other causes no records were made on seven days in July, six days in August, and nine days in September.

The signal at 10 p. m. on July 26 and the special signal at 3 a. m., July 27, 1925, were ended about one minute early, and the signal at 10 p. m., June 1, 1926, was about one second late. Another correct signal was sent on the next hour. Excepting as noted above the maximum error of any signal was 0.19 second, and the average error of all signals was 0.031 second.

The following table gives the results obtained from automatic reception of signal sent from the Lafayette radio station at Bordeaux, France. Owing to delay in receiving the Paris times of these signals, the results are given for the calendar year of 1925 instead of the fiscal year:

Month	Washington-Paris	Number of days	Month	Washington-Paris	Number of days
	Second			*Second*	
January	+0.19	21	July	+0.08	21
February	+0.05	19	August	+0.05	17
March	+0.06	17	September	+0.12	18
April	+0.05	18	October	+0.09	13
May	+0.14	22	November	+0.13	17
June	+0.11	20	December	+0.17	17

Chronometers, torpedo-boat watches, patrol-boat watches, clocks, and watches.—One chronometer trial was held during the year, beginning January 12 and ending June 19, 1926. No new chronometers were received for test, and very few torpedo-boat watches were on hand for test. For several years it has been the policy to issue patrol-boat watches, of which large numbers have been in stock, rather than purchase new torpedo-boat watches. The accompanying table gives data of old chronometers making a trial number not greater than 35.

The following timepieces were received during the year:

Chronometers:	
Old, for trial	152
Old, for repairs	192
Torpedo and patrol-boat watches and patrol-boat chronometers:	
Old, for test	248
Old, for repairs	258

Stop and comparing watches:	
New, for test	265
Old, for test	337
Deck, boat, airplane, and wall clocks:	
New, for test	8
Old, for test	647

All timepieces except chronometers, torpedo and patrol-boat watches, and patrol-boat chronometers were turned over to the supply officer for stock after test. The following were issued during the year by the time service:

Chronometers:	
For use	149
Rejected to owners	7
Torpedo and patrol-boat watches and patrol boat chronometers: For use	136

SUPPLY DIVISION

[Mr. F. J. Hallock, assisting supply officer until March 15, 1926]

Value of stock on hand July 1, 1925	$2, 051, 015. 20
Value of instruments, etc., purchased	58, 574. 90
Value of instruments, etc., from stations and ships	200, 527. 11
	2, 310, 117. 21
Value of instruments, etc., issued and expended	229, 674. 33
Value of stock on hand June 30, 1926	2, 080, 442. 88
	2, 310, 117. 21

	This year	Last year
Number of shipments received	1, 469	1, 497
Number of instruments and parts received	47, 920	40, 821
Number of shipments made	1, 523	1, 202
Number of instruments and parts shipped	29, 673	36, 065

The supply division through shorthandedness of personnel labored under difficulties in meeting as best they could, in addition to the accounting and routine of the office, the requirements of the Bureau of Supplies and Accounts in reference to prompt rendition of returns. This handicap was further increased during the last quarter of the fiscal year by the resignation on March 15 of the assistant to the supply officer, Mr. Hallock, leaving but one clerk in the office. This situation was relieved on the 15th of April when a clerk was appointed to fill the vacancy of Mr. Neely, promoted, vice Hallock resigned. Another clerk was appointed to this division on April 16, and it is now hoped that after a few months' training in the work of the office, this increased force will be able more nearly to meet the heavy demands placed upon it.

INSPECTION DIVISION

[Commander Harry Kimmell, United States Navy (retired), in charge]

Very few new instruments have been purchased during the year except in aviation. The shop work has been increasing especially in original and repair work in aviation. Much material bought has been for repairs.

The following is a list of instruments repaired during the year:

Alidades	4
Altimeters	510
Anemometers	8
Azimuth circles	106
Barographs	12
Barometers	106
Binoculars	247
Chronometers	148
Chronometer boxes	100
Clinometers	13
Clocks	688
Compasses	203
Compasses (aero)	462
Drafting machines	3
Miscellaneous instruments (Nav.)	31
Magnets	151
Mirrors resilvered	1, 127
Peloruses	12
Plotting boards	6
Protractors, 3-arm	24
Psychrometers	8
Sextants	190
Spy-glasses	562
Stadimeters	17
Telescopes	13
Thermographs	4
Theodolites	9
Transits	29
Watches	354
Miscellaneous instruments:	
Aero	11
Astron	4
Surveying	9
Total	5, 171

DEPARTMENT OF NAUTICAL ALMANAC

[Capt. W. S. Eichelberger (Math.), United States Navy, director]

The American Ephemeris and Nautical Almanac for 1928 was received from the printer on April 5, 1926, and the American Nautical Almanac for 1928 on June 7, 1926.

All the copy of the American Ephemeris and Nautical Almanac for 1929 except 16 pages has been sent to the printer, and 402 pages are in type.

The investigation of the orbits of Saturn's satellites has been continued. One hundred and forty-nine sets of corrections to the elements have been obtained from 18 pairs of satellites, and equations of condition have been formed for 46 more sets, covering in all 22 oppositions.

The work on the determination of the orbit of Neptune's satellite based on 1,639 observations made during 33 oppositions from 1889 to 1923 is in type and should be off the press in a few months. A full account of the results obtained is given in M. N. R. A. S., for March, 1926.

DEPARTMENT OF ASTRONOMICAL OBSERVATIONS

DIVISION OF 6-INCH TRANSIT CIRCLE

[Astronomer J. C. Hammond, in charge]

Observations of the sun, moon, and planets have been continued through the year in addition to the observations for time which have been made with a Prin portable transit as well as with the 6-inch.

The number of observations made during the year is:

	6-inch	Prin.		6-inch	Prin.
Sun	172		Neptune	17	
Moon	126		Clock stars	2, 008	
Mercury	73		Time stars	678	307
Venus	114		Azimuth stars	299	45
Jupiter	11				
Saturn	21		Total	3, 534	352
Uranus	15				

The following table gives a comparison of the clock corrections determined with the Prin and 6-inch for each month. A constant correction for clamp difference, ±0.016 second, has been applied to the clock corrections of the 6-inch to reduce to the mean of the two clamps. The differences are in the sense Prin minus 6-inch.

Month	Difference in clock corrections	Number of nights	Month	Difference in clock corrections	Number of nights
1925	*Second*		1926	*Second*	
July	+0.019	5	January	−0.026	4
August	+.009	5	February	+.012	4
September	−.007	4	March	+.011	4
October	+.002	4	April	+.021	4
November	+.012	4	May	−.020	4
December	−.028	5	June	+.022	4

The 6-inch was reversed 47 times and the number of determinations of its instrumental constants is:

Collimation	450	Marks	642
Level	639	Nadir	706

The manuscript of the observations made during the period 1909–1918 was sent to the Government Printing Office in April to be printed. This publication is to be Volume XI, second series, publications of the United States Naval Observatory, and will contain a discussion of the observations made during this period and a catalogue of fundamental stars, including those of Backlund and Hough, referred to the equinox 1910.0.

CLOCK VAULT

The temperature in the clock vault was maintained practically constant at 84° F. during the year. Riefler clock No. 60 was used as the standard clock. Riefler No. 151 was unsealed on October 27, 1925, to adjust the winding contact.

The following table gives the mean daily rates of the three Riefler clocks in the vault and the maximum variations in the rates for each month:

Month	No. 60		No. 70		No. 151	
	Mean daily rate	Maximum variation	Mean daily rate	Maximum variation	Mean daily rate	Maximum variation
1925	*Second*	*Second*	*Second*	*Second*	*Second*	*Second*
July	+0.16	0.03	+0.10	0.02	+0.08	0.04
August	+.15	.02	+.07	.05	+.02	.05
September	+.17	.02	+.04	.03	−.03	.05
October	+.19	.02	+.02	.02	−.05	.02
November	+.20	.01	+.03	.02	+.05	.05
December	+.21	.02	+.04	.04	+.03	.03
1926						
January	+.19	.02	+.05	.02	+.02	.02
February	+.18	.03	+.03	.02	+.02	.02
March	+.18	.03	+.01	.07	−.01	.04
April	+.15	.05	−.01	.03	−.04	.03
May	+.09	.06	−.06	.07	−.10	.06
June	+.05	.02	−.10	.03	−.13	.01

Total variation in daily rate during the year:

	Second
No. 60	0. 16
No. 70	. 22
No. 151	. 22

DIVISION OF 9-INCH TRANSIT CIRCLE

[Astronomer H. R. Morgan, in charge]

The observing program begun with this instrument in August' 1913, has been completed. As indicated in the report for 1914, the observing list included about 7,561 "intermediary" stars (7.0 to 9.5 magnitudes), between +90° and −30° declination; 1,414 "standard" stars, (5.0 to 7.0 magnitudes), between +90° and −36° declination; and 1,024 other stars in the fundamental catalogues and National Ephemerides. In the first two classes the stars are uniformly spaced in the sky and together give five stars per hour per zone 2° wide. The list contains all stars in "Bulletin du Comité International Permanent pour l'exécution photographique de la Carte du Ciel, Tome Septième" to −30° declination, and all stars in "Liste Générale Provisoire D'Étoiles Fondamentales" ("Supplément a la Connaissance des Temps pour l'an 1914"), culminating at less than 75° zenith distance at Washington.

From August, 1913, to July, 1918, each star was observed once in each clamp of the instrument. The reading circle was then shifted on its pivot and from September, 1918, to June, 1926, each star was observed once more in each clamp, giving in all four observations of each of the 10,000 stars of the list. The standard and fundamental stars above 66° declination were observed also four times below pole.

The moon and outer planets were observed from August, 1913, to February, 1925, and the sun, Mercury, Venus, and day stars from September, 1918, to February, 1925. The approximate number of observations of the various objects made in the 13 years is given below.

Intermediary stars	32, 400	Day stars	3, 600
Standard stars	10, 580	Sun	600
Clock stars	16, 800	Moon	870
Azimuth stars	3, 000	Planets	1, 150
Zenith and refr. stars	1, 000		
R. and D. stars	2, 330	Total	72, 330

The work also includes 29,750 determinations of collimation, level, azimuth, and nadir constants; 150 sets of measures on the horizontal and vertical collimators for flexure; 700 sets of measures on the personal equation machine; several determinations of the forms of the pivots; and many other investigations.

The preliminary reductions are partly finished to 1922 and the results entered on the card catalogue to 1918. It will take a number of years to finish the reductions of this work, and the personnel of this division is engaged upon these reductions.

DIVISION OF THE EQUATORIALS

[Commander Asaph Hall (Math.), United States Navy (retired), in charge]

26-INCH EQUATORIAL

Observations have been made as follows:

Comparison stars	2	Comet 1926b (Blathwayt)	1
Occultations	18	Asteroid Nestor (659)	4
Comet 1925c (Orkisz)	1	Satellites of Saturn	25
Comet 1925d (Tempel II)	2	Satellites of Uranus	9
Comet 1925f (Borrelly)	5	Satellite of Neptune	5
Comet 1925j (Van Biesbroeck)	9		

Determinations of the following were also made:

Parallels	54
Coincidences	9

There were visitors at the 26-inch on 74 nights. There were about 600 visitors.

In August the driving clock of the 26-inch was dismounted and cleaned by the instrument maker. One-sixty-fourth inch was planed from the cast iron block to which the box containing the driving worm is attached, in order to make the worm screw mesh better with the large driving wheel.

12-INCH EQUATORIAL

With this instrument were observed 20 occultations, also 4 observations were made of Comet 1925k (Peltier-Wilk).

The observatory was open to visitors by card for viewing the heavens through this instrument on 110 nights, of which 35 were cloudy. There were 1,513 visitors, including those received on special nights assigned to schools.

In September the instrument maker removed the 12-inch driving clock from the telescope pier and cleaned it. The counterpoising of this instrument was improved; the finder was moved along the tube, nearer the object glass; new brushes were made to carry the current which lights the circles, the prisms of the reading microscopes were polished, and a double slide rheostat was mounted on the tube to regulate the lighting of the two sets of micrometer threads.

The reductions in the observing books are completed nearly to July 1, 1926.

The preparation of the equatorial volume is well advanced.

PHOTOGRAPHIC TELESCOPE

One of the pair of 10-inch photographic triple lenses of this instrument was dismounted May 5, 1925, for use at the total solar eclipse of January 14, 1926. On May 15, 1926, this objective was returned to the Naval Observatory with other eclipse apparatus.

On account of eclipse preparations and other work no observations of asteroids were made with this instrument during the fiscal year.

It is proposed to attempt a readjustment of this triple lens, to secure more perfect definition over the entire field before remounting. A method devised by Dr. J. A. Anderson of the Mount Wilson Solar Observatory Laboratory, Pasadena, Calif., will be employed.

A list of asteroid positions, completing those which have been observed here photographically has been sent to the Astronomical

Journal for publication. Observations of asteroids made with this telescope have been measured and reduced to date. They are now in process of arrangement for publication in the forthcoming equatorial volume.

THE PHOTOHELIOGRAPH

Observations of the sun with the photoheliograph were made on 218 days. Solar spots or groups were observed on 216 of these photographs. This is a considerable increase in spots over the previous year, when with observations on 247 days, 34 days were without spots on the sun.

During Mr. Peters's absence with the Sumatra eclipse expedition from August 21, 1925, to April 7, 1926, the photographs and records with this instrument were made mostly by Mr. Harrison. This included transmitting a copy of the record by postcard to the Western Union Telegraph Co. at New York.

A still further increase in the number and size of solar groups and spots for the next two years is probable. An increase in the number and intensity of magnetic disturbances is expected during this period. Unless delayed, as sometimes happens, the maximum of the present sun spot cycle should occur about the latter part of 1928. The last minimum was in the summer of 1923.

A plan has been suggested and worked out by Mr. Watts and Miss Lamson jointly for measuring the coordinates of solar phenomena from the photographs. The method involves the use of a measuring instrument, constructed by the instrument maker. Copies of standard plotted charts photographed on glass were made, from which the heliocentric latitudes and longitudes of solar spots or groups may be read. Areas in square degrees will be measured by an auxiliary glass scale. The reliability of this process by the measurement of a number of solar photographs made with the photoheliograph, has already been demonstrated.

DIVISION OF THE PHOTOGRAPHIC ZENITH TUBE AND ALT-AZIMUTH

[Capt. F. B. Littell (Math.), United States Navy, in charge]

PHOTOGRAPHIC ZENITH TUBE

During the absence of Captain Littell on the Sumatra eclipse expedition, Astronomer G. A. Hill was in charge of this division. The number of observations secured during the year was 1,907. The publication of the results for 1925 has been delayed by the absence of the head of the division and by the occurrence of some abnormal results in the latter part of the year, apparently due to trouble with the mercury reflecting surface. This part of the work is still under consideration.

ALT-AZIMUTH

On account of the accumulation of reduction work in the observatory, it has been deemed advisable to omit observations with this instrument during the year.

DIVISION OF THE PRIME VERTICAL TRANSIT

[Astronomer George A. Hill, in charge]

The plan of work which in part covers observations to be made of the positions of certain selected stars has been continued. The observations to be made of these stars are nearly finished, except for a gap which occurs between two and seven hours of right ascension. The reduction of the observations already secured has proceeded during the year.

The reading of the final proof of the contents of the Prime Vertical Volume, namely, Volume X, Part I, of Naval Observatory Publications, second series, was finished on February 16, 1926. The corrected proof was returned to the Government Printing Office the next day.

During the absence of Professor Littell on the eclipse expedition to Sumatra the division of the photographic zenith tube and alt-azimuth was placed in charge of Mr. Hill.

Between February and May seven naval officers assigned to survey duty on the U. S. S. *Niagara*, *Galveston*, and *Tulsa*, respectively, were ordered to temporary duty at the Naval Observatory, at the request of the hydrographer of the Navy. The purpose was to give each of these officers an opportunity to receive special instructions in the use and adjustment of certain surveying instruments which they were to use.

Those instructions were given by Mr. Hill. One of the above officers, Ensign K. Earle, in addition to the above, received specific instructions in the method of observing with a combined transit instrument and zenith telescope. From the observations to be made by him basic reference points in the surveys are to be secured.

This course of instruction given Mr. Earle extended over a period of two months, and in this time he was taught how to secure time sights from selected stars, under field conditions, and also how the latitude of the instrument was obtained using pairs of stars in accordance with Talcott's method.

COMPUTING DIVISION

[Under the direction of the executive committee and of Associate Astronomer Eleanor A. Lamson, supervisor]

For the 9-inch transit circle.—Work has been done on the clock sheets from February to June, 1925; on right ascension and declination reductions from July, 1920, to December, 1921. Reductions to mean place have been computed from February to August, 1919.

For the 6-inch transit circle.—Work has been done on the declination reductions from May, 1925, to May, 1926. Proofs of the illustrations and sample pages of Volume XI, Publications of the United States Naval Observatory, second series, have been examined. A series of Bordeaux time signals received in the summer of 1925 has been read.

For the equatorials.—Work has been done on the reductions in the current observing books and in preparation of material for publication. This included computations of corrections to the elements of the orbits of the satellites of Mars, opposition of 1924, measuring and reduction of asteroid plates, and the preparation and use of glass slides for a sun-spot measuring machine.

LIBRARY

[Mr. W. D. Horigan, librarian]

	Volumes	Pamphlets	Total
Contents of the library July 1, 1925	32,711	6,287	38,998
Accessions:			
By purchase	22	0	22
Through exchange	135	121	256
Total	32,868	6,408	39,276

There were distributed 6,384 publications of the institution, including 544 copies of the American Ephemeris and Nautical Almanac for 1926 and 2,382 copies of the American Nautical Almanac for 1926.

CONTRIBUTIONS TO CURRENT ASTRONOMICAL LITERATURE

The following publications have appeared in the Astronomical Journal during the year ending June 30, 1926:

1. Observations of 70 Ophiuchi, Ernest Clare Bower. (No. 851.)
2. Variation of Latitude at Naval Observatory, F. B. Littell. (No. 852–853.)
3. Observations of Comets, H. E. Burton. (No. 852–853.)
4. Use of a General Relation of Orbital Coordinates in the Expeditious Interpolation of Solar Coordinates, J. E. Willis. (No. 855.)
5. Observations of Comets, Ernest Clare Bower. (No. 856.)
6. Observations of Asteroids, Ernest Clare Bower. (No. 859.)
7. Observations of (659) Nestor, H. E. Burton. (No. 859.)
8. Occultations by the Moon, Asaph Hall, Ernest Clare Bower, and H. E. Burton. (No. 859.)
9. Observations of the Moon, J. C. Hammond and C. B. Watts. (No. 861.)
10. Observations of Comets, H. E. Burton. (No. 861.)

Other contributions:

Orbit of Neptune's Satellite and Pole of Neptune's Equator, W. S. Eichelberger and Arthur Newton, Monthly Notices, volume 86, No. 5.

The following papers were read before scientific societies by the superintendent:

The Naval Observatory, its functions, with special reference to "time"; Why the Naval Observatory furnishes the time for the United States. Before the Horological Institute of America, May 13, 1926.

The Naval Observatory and the eclipse of 1925. Before the Engineers Society of Washington, March 17, 1926.

BUILDINGS AND GROUNDS

General repairs and upkeep of the buildings and grounds, together with the routine work necessary for the general care, preservation, and orderly appearance of a public reservation, has taxed the capacity of the small force available for the purpose to the utmost, because the limitations in appropriations for the above purposes since the fiscal year 1922 allows for the employment of only four laborers instead of the six of former years. However, in addition to the routine repair, cleaning, and upkeep, the following items out of the ordinary routine have been completed by the force available, utilizing the firemen off watch and the inside laboring force when available.

Repairs to roofs.—Cemented pinholes in roof of main building and library. Cemented flashings and joints in copper gutters, and painted roofs of same and other copper-covered roofs with a second coat of "Rustnaught" paint which, judging from the results obtained from the application of the first coat put on last year, should protect them from further deterioration for several years.

Repairs to elevators.—Put in new piping on water-feed line, connected it up with a 2½-inch water pipe; overhauled and repacked elevator cylinder of main building, and the four hydraulic rams of elevating floor of 26-inch equatorial, jacked up dome of latter, and tightened up on roller bearings and greased tracks.

Assisted the instrument maker in dismantling and assembling the clock drive of 26-inch equatorial when repairs were required to it. The instrument maker, Mr. Ilse, deserves great credit for the expeditious and economical repairs made to this large and at the same time delicate piece of mechanism.

Painted walls and ceilings of all offices but two on the second floor of main building, together with east and west stairway halls.

Scraped and painted south transit building and 12-inch equatorial dome and house.

Shifted workshop of instrument maker from cellar to a better location in the pier room of main building.

The following contracts for repairs to buildings and improvement of the grounds were let:

By Bureau of Yards and Docks to Pittsburgh-Des Moines Steel Co. with money appropriated for the purpose by Congress—the installation of new 8-inch water main and fire system complying with the District of Columbia fire regulations to replace old and worn-out original system, at a cost of $13,864.37.

By General Supply Committee to Sidney L. Hechinger, the sale and removal of obsolete water tower of old system, by which the Government was reimbursed to the amount of $1.01.

By Naval Observatory to Muller & De Jarnette for repairs to metal work of 9-inch transit circle building, cost $195.

By Naval Observatory to same firm for repairs to metal shutters of 26-inch equatorial building, cost $173.

By Naval Observatory to same firm for repairs to roof of porch of superintendent's quarters, cost $85.

By Naval Observatory to V. L. Wooldridge for relining and repairs to brickwork in furnaces of heating plant, cost $294.

By Naval Observatory to A. W. Lee for repairing and replastering in basements of astronomers' quarters, cost $450.

By Secretary of the Navy (Judge Advocate General's office) to Clinton Ward for replacements to concrete walks, cost not over $850. Work on this contract not started until after the 1st of July.

Owing to the small force allowed, the grounds and roads can not be said to be in better than fair condition.

E. T. Pollock.

Approved.

W. R. Shoemaker,
Chief of Bureau of Navigation.

TABLE I.—*Data of trial of old chronometers at the United States Naval*

[The signs are astronomical, + losing − gaining. Data of

								Mean daily rates			
								Special temperatures			
Temperature………degrees F..								90.0	85.0	70.0	55.0
	Balance: o=ordinary. v=invar. a=auxiliary. Hairspring: p=palladium. s=steel.				Point of compensation			Jan. 12 to 19	Jan. 21 to 28	Jan. 30 to Feb. 6	Feb. 8 to 15
Order of merit	Chronometer	Kind	Trial number	Balance, hairspring	Temperature	Rate	Temperature constant				
					°	s		s	s	s	s
1	Bliss……3203	M. T. S.	1. 69	o. p.	70. 2	−1. 05	+0. 00091	−0. 64	−0. 86	−1. 01	−0. 91
2	Bliss……2961	M. T. S.	4. 66	o. s.	51. 5	−1. 20	+0. 00067	−0. 24	−0. 41	−1. 07	−1. 24
3	Leroy……1232	M. T. S.	5. 84	v. s.	−72. 5	−0. 06	−0. 00004	−1. 03	−1. 33	−1. 04	−0. 87
4	Nardin……1654	M. T. S.	8. 27	v. s.	77. 5	+0. 56	−0. 00024	+0. 76	+0. 61	+0. 57	+0. 20
5	Bliss……3129	M. T. S.	8. 35	o. p.	65. 9	+0. 47	+0. 00156	+1. 06	+1. 06	+0. 43	+0. 56
6	Bliss……3075	M. T. S.	9. 12	o. p.	65. 6	−0. 02	+0. 00107	+0. 14	+0. 21	−0. 11	−0. 13
7	Bond……610	M. T. S.	9. 81	o. s.	71. 9	−0. 61	+0. 00213	+0. 06	−0. 13	−0. 59	0. 00
8	Dent……48421	M. T. S.	9. 83	a. s.	122. 5	−1. 09	+0. 00002	−1. 00	−1. 07	−1. 13	−1. 19
9	Bliss……3114	M. T. S.	10. 20	v. s.	100. 0	−0. 29	+0. 00076	−0. 04	−0. 08	+0. 31	+1. 14
10	Negus……1697	M. T. S.	11. 28	o. s.	70. 8	−1. 16	+0. 00258	+0. 03	−0. 53	−0. 99	−0. 39
11	Bliss……2973	M. T. S.	12. 64	o. p.	87. 5	+0. 48	+0. 00053	+0. 63	+0. 29	+0. 40	+0. 87
12	Bliss……3113	M. T. S.	12. 72	v. s.	370. 0	−8. 04	+0. 00009	−0. 80	−0. 64	−0. 13	+0. 83
13	Bond……555	M. T. S.	12. 76	o. s.	75. 1	−1. 66	+0. 00222	−1. 09	−1. 40	−1. 50	−0. 74
14	Bond……556	M. T. S.	12. 83	o. s.	69. 4	−0. 64	+0. 00311	+0. 53	+0. 29	−0. 54	+0. 04
15	Frodsham……2307	M. T. S.	12. 95	o. s.	72. 8	+0. 83	+0. 00280	+1. 21	+1. 33	+0. 83	+1. 79
16	Leroy……1178	M. T. S.	13. 55	v. s.	640. 0	+15. 69	−0. 00004	+1. 46	+1. 69	+0. 81	−0. 26
17	Nardin……1599	M. T. S.	13. 58	v. s.	100. 0	+1. 72	+0. 00013	+1. 46	+1. 46	+1. 53	+1. 89
18	Ehrlich……786	M. T. S.	13. 96	o. s.	86. 8	−0. 57	+0. 00118	−0. 81	−0. 84	−0. 56	+0. 59
19	Dent……2757	M. T. S.	14. 07	o. s.	72. 3	+1. 39	+0. 00271	+2. 33	+2. 16	+1. 39	+2. 06
20	Negus……1449	M.T.B.C.	14. 07	o. s.	68. 3	+0. 84	+0. 00247	+1. 63	+1. 86	+1. 03	+1. 33
21	Negus……1283	M. T. S.	15. 04	o. s.	64. 1	−0. 48	+0. 00244	+1. 43	+0. 77	−0. 20	−0. 24
22	Bond……517	M. T. S.	15. 18	o. s.	70. 3	−1. 51	+0. 00364	−0. 20	−0. 71	−1. 49	−0. 57
23	Knoblich……2112	M. T. S.	15. 45	o. s.	67. 2	+1. 25	+0. 00336	+2. 84	+2. 33	+1. 30	+1. 76
24	Negus……1343	M. T. S.	15. 51	o. s.	76. 1	+2. 59	+0. 00238	+2. 73	+2. 94	+2. 89	+3. 47
25	Negus……1308	M. T. S.	15. 54	o. s.	66. 8	−0. 08	+0. 00253	+1. 33	+0. 83	−0. 13	+0. 06
26	Bond……327	M. T. S.	15. 60	o. s.	61. 7	+3. 19	+0. 00216	+5. 17	+4. 53	+3. 40	+3. 29
27	Ehrlich……835	M. T. S.	15. 70	o. s.	65. 6	+0. 04	+0. 00218	+1. 63	+1. 09	+0. 20	−0. 07
28	Ehrlich……1016	M. T. S.	15. 72	o. s.	61. 8	+0. 92	+0. 00096	+1. 67	+1. 37	+0. 97	+0. 87
29	Bliss……2966	M. T. S.	16. 22	o. p.	72. 7	−2. 33	+0. 00098	−1. 83	−2. 06	−2. 49	−2. 09
30	Black……4164	M. T. S.	16. 95	o. s.	69. 8	+1. 64	+0. 00311	+2. 41	+2. 27	+1. 57	+2. 21
31	Hand……{1017 9345}	M. T. S.	17. 62	a. s.	65. 0	+1. 10	+0. 00251	+2. 86	+2. 17	+1. 29	+1. 23
32	Bliss……2934	M. T. S.	17. 93	o. p.	81. 8	−0. 71	+0. 00109	−0. 89	−0. 91	−0. 94	−0. 30
33	Dent……47671	M. T. S.	18. 42	a. s.	65. 1	+2. 02	+0. 00178	+4. 44	+2. 94	+2. 07	+2. 10
34	Bliss……2890	M. T. S.	19. 69	o. s.	61. 7	+0. 80	+0. 00173	+1. 99	+1. 61	+0. 77	+0. 89
35	Negus……1232	M. T. S.	20. 27	o. s.	68. 5	−1. 43	+0. 00327	+0. 06	−0. 36	−1. 14	−0. 80
36	Kulberg……1570	M. T. S.	20. 70	o. s.	65. 8	−0. 11	+0. 00289	+1. 54	+1. 06	+0. 10	+0. 13
37	Bruce……5058	M. T. S.	21. 66	o. s.	67. 0	+0. 85	+0. 00338	+2. 49	+1. 74	+0. 90	+1. 43
38	Dent……48831	M. T. S.	21. 69	a. s.	99. 4	+1. 78	−0. 00107	+1. 66	+1. 47	+0. 74	−0. 67
39	Crisp……466	M. T. S.	22. 36	o. s.	56. 4	+0. 21	+0. 00178	+2. 33	+1. 60	+0. 57	+0. 79
40	Bond……552	M. T. S.	23. 11	o. s.	64. 1	+0. 68	+0. 00289	+1. 97	+2. 03	+0. 96	+1. 11
41	Bond……596	M. T. S.	23. 32	o. s.	87. 5	−1. 24	+0. 00229	−0. 73	−1. 00	−0. 29	+1. 07
42	Mercer……10662	M. T. S.	24. 67	o. s.	64. 9	+0. 14	−0. 00140	−0. 33	−0. 60	+0. 13	+0. 33
43	Negus……1754	M. T. B. C.	25. 96	o. s.	64. 8	+4. 00	+0. 00287	+5. 23	+5. 01	+3. 97	+4. 09
44	Bond……477	M. T. S.	26. 12	o. s.	68. 4	−1. 07	+0. 00204	−0. 03	−0. 70	−0. 93	−0. 56
45	Bond……509	M. T. S.	26. 85	o. s.	64. 6	−2. 01	+0. 00300	−0. 20	−0. 56	−1. 77	−1. 66
46	Bliss……3085	M. T. S.	27. 06	o. p.	72. 5	+2. 08	+0. 00447	+3. 00	+2. 71	+2. 03	+3. 44
47	Negus……1065	M. T. S.	30. 28	o. s.	72. 1	−0. 31	+0. 00211	+0. 29	0. 00	−0. 31	+0. 19

Observatory, Washington, D. C., January 12, 1926, to June 19, 1926

chronometers with trial number greater than 35.00 omitted]

Mean daily rates—Continued															
Special temperatures—Continued						Ordinary temperatures									
50.0	50.0	55.0	70.0	85.0	90.0	71.0	66.0	68.3	70.3	71.2	69.2	68.3	69.0	69.4	72.9
Feb. 17 to 24	Feb. 24 to Mar. 3	Mar. 5 to 12	Mar. 14 to 21	Mar. 23 to 30	Apr. 1 to 8	Apr. 10 to 17	Apr. 17 to 24	Apr. 24 to May 1	May 1 to 8	May 8 to 15	May 15 to 22	May 22 to 29	May 29 to June 5	June 5 to 12	June 12 to 19
s	s	s	s	s	s	s	s	s	s	s	s	s	s	s	s
−0.57	−0.63	−0.76	−1.09	−0.84	−0.80	−1.10	−0.90	−0.94	−0.94	−1.07	−0.97	−0.96	−0.97	−1.07	−1.00
−1.11	−0.99	−1.14	−0.87	−0.49	−0.23	−0.89	−1.07	−0.90	−0.86	−0.84	−0.81	−0.79	−0.80	−0.84	−0.67
−0.57	−0.61	−0.70	−0.89	−1.00	−1.04	−1.21	−1.17	−1.11	−1.00	−1.19	−0.90	−0.73	−0.97	−0.76	−0.91
+0.43	+0.29	+0.67	+0.53	+0.49	+0.40	0.00	+0.16	+0.31	+0.11	+0.33	+0.54	+0.54	+0.60	+0.76	+0.67
+0.94	+1.10	+0.76	+0.57	+1.03	+1.10	+0.33	+0.23	+0.43	+0.46	+0.36	+0.53	+0.59	+0.60	+0.70	+0.87
−0.01	+0.06	+0.34	+0.11	+0.56	+0.69	+0.60	+0.59	+0.49	+0.40	+0.47	+0.67	+0.86	+0.83	+0.86	+0.70
+0.33	+0.36	0.00	−0.61	−0.36	−0.13	−0.70	−0.57	−0.67	−0.76	−0.94	−0.91	−0.93	−1.00	−1.00	−1.31
−1.33	−1.19	−0.79	−0.93	−1.04	−1.17	−1.27	−1.26	−1.14	−1.13	−0.94	−0.81	−0.76	−0.56	−0.64	−0.54
+1.36	+1.59	+1.33	+0.47	−0.21	−0.03	+0.54	+1.11	+0.86	+0.61	+0.41	+0.41	+0.66	+0.50	+0.46	+0.29
−0.14	−0.43	−0.64	−1.33	−0.76	−0.19	−1.10	−1.07	−1.10	−1.00	−0.97	−0.81	−0.86	−0.77	−0.94	−0.79
+1.39	+1.50	+1.21	+0.89	+0.66	+0.54	+0.49	+0.70	+0.63	+0.51	+0.26	+0.47	+0.89	+0.91	+1.11	+0.91
+1.04	+0.66	+0.73	+0.04	−1.00	−0.90	−0.33	+0.21	+0.21	−0.09	−0.53	−0.10	−0.14	−0.30	−0.41	−0.59
−0.49	−0.33	−0.79	−1.71	−1.49	−1.11	−0.96	−1.13	−1.49	−1.67	−1.50	−1.47	−1.46	−1.69	−1.50	−1.57
+0.69	+0.67	−0.04	−0.73	−0.04	+0.69	−0.77	−0.54	−0.76	−0.76	−0.77	−0.80	−0.74	−0.79	−0.57	−0.96
+2.46	+2.46	+1.66	+0.87	+1.16	+1.84	+1.16	+1.09	+1.03	+1.06	+0.90	+1.36	+1.01	+1.06	+1.20	+1.10
−0.49	−0.39	+0.03	+0.49	+1.11	+1.57	+0.74	+0.94	+0.64	+0.77	+0.70	+0.67	+0.74	+0.54	+0.50	+0.57
+2.19	+2.09	+2.09	+2.14	+2.04	+1.86	+1.71	+1.90	+2.00	+2.20	+1.99	+2.20	+2.47	+2.21	+2.60	+2.43
+0.93	+0.81	+0.66	+0.07	−0.30	−0.64	−0.83	−0.36	−0.34	−0.61	−0.66	−0.46	−0.19	−0.34	−0.26	−0.50
+2.79	+2.80	+2.33	+1.41	+1.47	+2.23	+1.19	+1.40	+1.19	+1.24	+1.04	+1.09	+1.44	+1.33	+1.37	+1.16
+1.73	+1.61	+1.24	+0.67	+1.20	+2.04	+1.04	+0.90	+0.83	+0.80	+0.73	+0.67	+0.57	+0.51	+0.89	+0.97
−0.06	−0.14	−0.31	−0.59	+0.39	+1.33	−0.26	−0.53	−0.54	−0.56	−0.61	−0.81	−0.81	−0.73	−0.80	−0.74
−0.31	−0.26	−0.74	−1.53	−0.74	−0.07	−1.26	−1.37	−1.20	−1.16	−1.33	−1.24	−1.29	−1.14	−1.26	−1.30
+2.14	+1.97	+1.74	+1.26	+2.30	+2.90	+1.30	+1.43	+1.46	+1.46	+1.36	+1.26	+1.64	+1.36	+1.31	+1.54
+3.93	+3.90	+3.83	+2.47	+2.63	+2.51	+2.03	+2.43	+2.13	+2.06	+1.97	+2.01	+2.17	+2.19	+2.24	+1.90
+0.40	+0.60	+0.43	+0.03	+0.76	+1.33	+0.21	+0.26	+0.24	+0.44	+0.37	+0.54	+0.79	+0.71	+0.81	+0.83
+3.71	+3.51	+3.29	+3.27	+4.19	+5.20	+3.33	+3.49	+3.59	+3.37	+3.17	+3.03	+3.13	+2.99	+3.24	+3.10
+0.36	+0.86	+0.64	−0.04	+0.63	+1.37	−0.23	−0.04	−0.01	+0.21	+0.17	+0.09	+0.16	+0.01	+0.06	−0.16
+0.77	+0.84	+1.06	+1.00	+1.49	+1.59	+0.84	+0.87	+0.97	+1.10	+1.14	+1.43	+1.67	+1.76	+1.69	+1.64
−1.37	−1.54	−1.94	−2.14	−2.30	−2.34	−2.89	−2.91	−2.76	−3.00	−2.81	−2.80	−2.53	−2.41	−1.81	−2.50
+2.89	+2.81	+2.43	+1.71	+2.46	+3.23	+1.81	+1.97	+1.80	+1.76	+1.59	+1.61	+1.93	+2.11	+2.33	+2.07
+0.77	+1.60	+1.47	+1.04	+2.04	+2.11	+1.26	+1.56	+1.33	+1.36	+1.53	+1.47	+1.29	+1.24	+1.11	+1.34
0.00	+0.11	+0.44	−0.19	−0.49	−0.64	−0.97	−0.89	−0.91	−0.89	−0.91	−1.07	−0.80	−0.84	−0.61	−0.46
+2.53	+2.50	+2.31	+2.04	+2.50	+3.29	+1.44	+1.46	+1.07	+1.14	+1.10	+1.06	+1.13	+0.93	+0.89	+1.07
+0.66	+0.26	+0.87	+1.06	+1.86	+3.06	+1.33	+1.29	+1.20	+1.33	+1.13	+0.87	+1.09	+1.13	+1.11	+0.66
−0.69	−0.07	−0.86	−1.71	−0.71	+0.03	−1.31	−1.33	−1.46	−1.54	−1.63	−1.87	−1.64	−1.60	−1.14	−1.19
+0.79	+1.17	+0.30	−0.21	+0.86	+1.50	−0.07	−0.17	−0.16	−0.27	−0.26	−0.56	−0.34	−0.79	−0.67	−0.69
+1.74	+1.66	+1.24	+0.87	+2.14	+2.46	+1.63	+1.59	+1.20	+1.21	+1.14	+0.94	+1.06	+0.97	+0.96	+1.00
−1.41	−1.40	+0.04	+0.99	+1.66	+2.36	+0.96	+0.47	+0.79	+1.00	+0.90	+0.66	+0.80	+1.07	+1.14	+1.46
+0.63	−0.16	−0.37	+0.50	+1.74	+1.84	+0.26	+0.53	+0.36	+0.37	+0.67	+0.79	+0.89	+0.70	+1.60	+1.39
+1.33	+1.24	+0.73	+0.59	+1.86	+2.16	+0.64	+0.84	+0.76	+1.10	+0.44	+1.10	+1.04	+0.99	+1.01	+1.24
+2.11	+2.20	+1.30	−0.79	−1.46	−1.30	−0.74	−0.19	−0.36	−0.76	−0.79	−0.70	−0.83	−0.86	−1.03	−0.97
−0.26	−0.80	−0.34	+0.07	−0.26	−1.69	−1.07	−0.64	−0.67	−0.69	−0.69	−1.13	−1.34	−1.49	−1.21	−1.50
+4.50	+4.50	+4.46	+4.19	+5.33	+6.07	+4.43	+4.57	+4.27	+4.50	+4.29	+4.29	+4.36	+3.76	+3.79	+3.76
−0.76	−0.53	−0.83	−1.20	−0.29	−0.04	−0.90	−0.93	−1.04	−1.06	−1.34	−1.66	−1.99	−2.03	−1.93	−1.57
−1.26	−1.36	−1.80	−2.07	−0.97	−0.14	−1.70	−1.49	−1.63	−1.60	−1.49	−1.36	−1.16	−0.84	−0.80	−0.74
+3.70	+4.21	+3.46	+2.19	+2.84	+3.20	+2.03	+2.39	+2.11	+2.11	+2.20	+2.09	+2.17	+2.31	+2.23	+2.31
+1.23	+1.14	+0.43	−0.30	+0.09	+0.63	−0.17	+0.07	−0.04	−0.27	−0.21	−0.61	−0.43	−0.71	−1.33	−1.37

APPENDIX NO. 2 TO ANNUAL REPORT OF THE
CHIEF OF THE BUREAU OF NAVIGATION, 1927

ANNUAL REPORT OF THE

NAVAL OBSERVATORY

FOR THE

FISCAL YEAR 1927

UNITED STATES
GOVERNMENT PRINTING OFFICE
WASHINGTON
1927

APPENDIX NO. 2

REPORT OF SUPERINTENDENT OF NAVAL OBSERVATORY

Navy Department,
United States Naval Observatory,
Washington, D. C., July 1, 1927.

From: Superintendent, Naval Observatory.
To: Chief of Bureau of Navigation.
Subject: Report of the Superintendent Naval Observatory for the fiscal year ending June 30, 1927.

Capt. Edwin T. Pollock, United States Navy, who was placed on the retired list of the Navy June 30, 1926, continued as superintendent.

The astronomical council, composed of the superintendent, the assistant superintendent, and six astronomers, continued its usual work throughout the year and was unchanged except for the detachment of the assistant superintendent, Capt. W. C. Asserson, United States Navy, on May 20, 1927, and addition of Astronomer James Robertson, assistant director, Nautical Almanac, June 23.

The Secretary of the Navy, on June 23, approved a modification of the order of July 29, 1908, establishing the astronomical council, so that the council is to include " such other assistants holding the rating of astronomer as the superintendent may designate " and also the assistant director of the Nautical Almanac.

The following changes occurred in the astronomical staff:

Resignation: Junior Astronomer Walter C. Myers, September 7, 1926; associate astronomer E. C. Bower, October 16, 1926.

Death: Associate Astronomer Arthur Newton, January 25, 1927.

Promotions: To associate astronomer George M. Raynsford, January 16; George F. Crawley, March 1, 1927; to assistant astronomer, John E. Willis, January 16; Morris Liferock, March 1, 1927.

Appointments: Junior astronomer, William M. Browne (temporarily in charge of the exhibit at the Sesquicentennial until December 15, 1926) January 1, 1927; John D. Phenix, June 17, 1927; junior library assistant, George C. Rodger, jr., July 1, 1926; temporary, Mrs. Ina R. Burton, April 1 to May 31, 1927; Mrs. E. V. Willis, October 14 to December 31, 1926.

Dismissal: C. de M. Lewis, May 26, 1927.

Carl L. Frederick assisted in the time service from May until December for the Marland Refining Co. in their gravity determinations for locating oil deposits.

The Naval Observatory continued to supply the Navy, the merchant marine, and the country, with the astronomical data required by navigators, astronomers, surveyors, and other scientists, and the " time " so essential to them and to all commercial activities. These time signals are the only official ones in the United States. Numerous private broadcasting radio stations have begun sending out the "time," but most of such are not accurate for scientific purposes, and some, unless reradiated from the Arlington signals, are not always accurate for commercial purposes. With the noon and 10 p. m. (eastern standard time) signals soon to be sent via Arlington on 24.9, 37.4, and 74.7 meters, in addition to the present ones on 435, 2,650, and 9,810 meters and on 17,145 meters via Annapolis, no one should be at loss for the "correct time."

The details of the regular and special time signals are given in another section, but the signals were used by the world longitude determination parties all over the world, by Canadian Government parties, by the United States Hydrographic Office, and United States Coast and Geodetic Survey parties in longitude determinations, and in gravity determinations by the United States Coast and Geodetic Survey, by scientists, and by prospectors for oil deposits. This increased use of the signals entails greatly increased work in the "time room," which is short-handed. The growing use by the general public and the desire for the "correct time" was indicated in November, 1926, when due to the Western Union Telegraph Co. having discontinued giving the "time" by phone in Washington, D. C., resulting in calls being made on the Naval Observatory; the number increased from 600 to 2,000 per day. To allow any business to be transacted over the phone, it was necessary on November 20 to discontinue the "telephone time service" altogether, placing Washington on the same footing as other cities.

The department of material has continued to furnish the Navy with navigation instruments, some of which have been remodeled and improved.

The nautical instrument repair shop, under Mr. Jacob Rheinbold and with its 15 skilled instrument makers, has continued its efficient work in effecting repairs.

A new Anschutz gyrocompass was given a trial on the U. S. S. *Memphis* in November, 1926, and was reported on by Lieut. Commander W. D. Chandler, jr., United States Navy, of the Observatory, and Lieut. J. C. Metzel, United States Navy, on duty with the U. S. S. *Saratoga*. Negotiations were started for the purchase of some of these compasses.

Over 2,870 visitors, including schools, have visited the observatory for a look through the telescopes.

Six officers took the compass course. Twelve officers were given instruction with astronomical and surveying instruments and in using them preliminary to going on surveying duty under the Hydrographic Office. Tables, etc., for their special work on the surveying grounds were prepared and furnished by the Naval Observatory.

World longitude determination observations during October and November, 1926, were made at San Diego, Calif., by Capt. F. B. Littell (Math.), United States Navy, Astronomer J. C. Hammond, and Associate Astronomer Paul Sollenberger, of the Naval Observatory staff, and Col. G. Mailles, French Army, and at the Naval Observatory by Associate Astronomer C. B. Watts; 748 observations were made at San Diego and 439 at Washington. The preliminary calculations show very gratifying results.

In connection with the observations at Paris and Greenwich, respectively, the results give 5 hours 17 minutes 36.659±.003 seconds as the difference of longitude for Paris-Washington against 5 hours 17 minutes 36.653±.003 seconds as determined in 1914, and the longitude from Greenwich as 5 hours 8 minutes 15.753±.002 seconds as against 5 hours 8 minutes 15.721±.014 seconds. This is the first time that the latter has been determined without the use of an intermediate station.

On February 10, 1927, a plate giving the latitude, longitude, and height above sea level of the "Zero mark," which is the reference point for all surveys in the United States, was installed in the clock house of the observatory, on the "meridian of Washington."

The Naval Observatory exhibit at the Sesquicentennial Exposition at Philadelphia was accorded a gold medal for its excellence.

Contributions and lectures on astronomical subjects by members of the observatory staff are enumerated further on.

Observations of stars to be used during the "Eros campaign" of 1930–31, when a new solar parallax will be determined, began January 1, 1927.

On January 1, 1927, the Naval Observatory, in connection with the Harvard, Mount Wilson, and Yerkes observatories, began to furnish data regarding daily sun spots for publication in the Monthly Weather Review of the Weather Bureau.

Congress on March 3, 1927, passed an act (H. R. No. 15541), authorizing the District of Columbia and the Naval Observatory to exchange certain lands, etc., whereby the circle of 1,000 feet radius contemplated by the act of August, 1894, will be completely owned by the Navy Department.

Publications issued, in press, etc.:

Vol. IX, Part III, Astronomical Papers of the American Ephemeris—The Orbit of Neptune's Satellite and the Pole of Neptune's Equator—was received from the printer March 15, 1927.

Vol. X, Part I, Naval Observatory Publications, second series (Prime Vertical volume, 1893–1912), was received from the printer July, 1926.

Vol. XI, Naval Observatory Publications, second series (Six-inch Transit Circle volume, 1909–1918), is still in the printer's hands in type.

Vol. XII, Naval Observatory Publications, second series (Equatorial volume, 1908–1926), was sent to the Navy Department with requisition for printing June 30, 1927.

The American Ephemeris and Nautical Almanac for 1929 was received from the printer May 14, 1927.

The American Nautical Almanac for 1929 went to press on May 26, 1927.

The American Ephemeris and Nautical Almanac for 1930 (except 67 pages) is in the printer's hands and 407 pages are in type.

Plans were completed for simultaneous observations of a special list of stars with five instruments—the 9-inch and 6-inch transit circles, the Prin transit, the alt-azimuth, and the photographic zenith tube—for ascertaining the performance of these instruments in determining the right ascensions and declinations of stars and the latitude of the Naval Observatory.

No appropriation for observing the eclipse of June 29, 1927, was asked of Congress, for two reasons: First, the time of totality was very short; second, and principally, owing to the small staff of the observatory and to the large amount of work on hand it has been considered undesirable to undertake eclipse expeditions for a few years. Naval Observatory apparatus has, however, been loaned a representative of the Smithsonian Institution for observing many eclipses, including that of June 29, 1927.

A member of the United States Coast and Geodetic Survey staff who participated at Honolulu in the world longitude determination spent several days at the Naval Observatory determining his "personal equation," using the apparatus that was used by the Naval Observatory observers at San Diego for that purpose.

DEPARTMENT OF MATERIAL[1]

Capt. W. C. Asserson, United States Navy, continued as assistant to the superintendent, head of the department, and supply officer until detached on May 20, 1927.

Commander W. H. Lee, United States Navy, remained in charge of the magnetic compass, aeronautical and aerological instrument divisions, until relieved June 8, 1927, by Lieut. M. F. Schoeffel, who reported on June 3.

INSPECTION OFFICE AT NEW YORK

Lieut. R. C. Bartman, United States Navy, reported for duty as assistant September 30, 1926, and Lieuts. H. Ernest and H. A. Anderson, United States Navy, were detached November 26 and 20, 1926, respectively. Lieut. H. Stevens reported to the inspector as assistant December 8, 1926.

The specific activities of the several divisions of the department follow in detail.

GYROCOMPASS DIVISION

[Lieut. Commander W. D. Chandler, jr., United States Navy,[2] in charge]

New installations.—Sperry Mark VIII, Model I gyrocompass equipments, were assigned to 14 destroyers, 2 light mine layers, and the *V-4*, and their installation directed.

Old salvaged Sperry Mark II, model 16 compasses, with necessary auxiliary equipments, were assigned to and ordered installed on the U. S. S. *Mercy*, *Vega*, *Bridge*, and *Sirius*.

Replacements.—Sperry Mark VIII, Model I equipments, were assigned and ordered installed on the U. S. S. *Decatur*, *Kidder*, and *Lamson* to replace Sperry Mark VI equipments. The compasses so removed will be used as tender spares.

Repair and upkeep facilities.—Compasses as listed were supplied to destroyer tenders for use as replacement spares to enable the tenders to place a spare compass on a destroyer while the vessel's own compass is undergoing overhaul on the tender:

Black Hawk, Sperry Mark VIII, Model I.
Altair, Sperry Mark VIII, Model I; Arma Mark II.
Whitney, Sperry Mark VIII, Model I.
Dobbin, Arma Mark II.

New developments.—The new Arma dead-reckoning tracer equipment for the U. S. S. *Texas* was delivered, passed acceptance tests, and its installation on the *Texas* commenced.

Modernization.—The project of modification of the Sperry Mark I and Mark II compasses to the mercury ballistic type (Mark II, model 16) by the navy yards at Norfolk and Puget Sound was continued. Twenty-one such compasses were completed during this fiscal year.

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[1] Changes only in personnel are given.
[2] Detached July 2, 1927.

MAGNETIC COMPASS DIVISION

[Commander William H. Lee, United States Navy, in charge]

The routine review of annual compass reports from vessels in commission has been completed. The situation with respect to magnetic compasses is satisfactory except that, having added a compensating boat binnacle and 5-inch compass to ships' allowance lists to be installed in power boats, it will be some time before the state of the funds will permit the purchase of a sufficient number completely to meet the demand. However, they are being purchased from time to time as funds become available.

Four regular and two reserve officers took the compass course.

Delivery of 400 bearing circles from the contractor has been practically completed. These have been assigned to vessels of the fleet for use with gyrocompass repeaters, and although they have not yet been in service a sufficient length of time to have called for any reports, it is anticipated they will fill a long-felt want.

Six experimental instruments have been fitted with telescopes of a new design and issued to the fleet. Experiments are now being conducted at the Naval Gun Factory to design an optical system for this instrument which will make the repeater card more readily visible.

When a satisfactory design has been worked out it is proposed to buy as many as funds will permit.

The pelorous situation for decommissioned destroyers has been solved and there are now on hand a sufficient number to equip these vessels in case of emergency.

The nautical-instrument repair shop has been constantly engaged to the limit of its capacity in the repair of magnetic compasses, azimuth circles, and other instruments.

AERONAUTICAL AND AEROLOGICAL INSTRUMENT SECTION

[Commander William H. Lee, United States Navy, in charge]

The Naval Observatory, in cooperation with the Bureau of Aeronautics, has continued to conduct experiments and correspondence in regard to the design, development, and issue of aeronautical and aerological material.

Flight experimentation has been continued with inductor compasses of the Pioneer type. These compasses are not considered to be suitable yet for service use. Five inductor compasses have been delivered by the General Electric Co., but have not been flight tested. The Bureau of Standards is continuing development of a brushless inductor compass based upon the principles of the Briggs-Heyl compass.

The modified NS II compass has continued to meet the needs of the service. Contract has been let for 1,000 parts for these compasses and it is the intention to modify them at the Naval Observatory repair shop for issue. As these modified compasses are issued the issue of the old NS II compasses will be discontinued and those now in service will be withdrawn for modification.

The late Lieut. Commander Noel Davis, United States Naval Reserves, in cooperation with Mr. M. L. Radford, of the Bureau of Ordnance, submitted the design of a new bubble sextant to the observatory which gives promise of being the best solution yet offered for the use of a bubble for the artificial horizon. Ten of these instruments are being manufactured for the Navy and it is expected that they will mark a great advance in this type of instrument. Fifteen Willson bubble octants embodying the improvements found to be advisable as the result of service experimentation have been ordered and are due for delivery.

Continued experiments with various methods for shortening the process of reduction of observations and plotting the results are being studied. It is the opinion that the use of the tables of Commander Radler de Aquino, Brazilian Navy, offers the best method yet tried. These tables are published under the title of "The Newest Navigation," and it is understood that a new set of tables is shortly to be published by the United States Naval Institute for Commander de Aquino, which will further facilitate the operation. Commander M. R. Pierce and Lieut. Commander P. V. Weems have proposed interesting methods which, not having yet been published, have not been thoroughly studied.

Continued experiments with various types of drift indicators and course and distance calculators have been made.

The observatory has kept in touch with our naval attachés in order to obtain the latest information in other countries regarding the development of navigational instruments for aircraft.

DIVISION OF NAUTICAL INSTRUMENTS AND TIME SERVICE

[Commander A. G. Sterling, United States Navy, in charge; Associate Astronomer Paul Sollenberger, technical assistant]

The division has continued its work with reference to nautical instruments and navigational equipment, as reported last year. Reconditioning of a large number of Navy standard binoculars at the optical shop, navy yard, Washington, D. C., was completed. This work will be continued during the coming fiscal year. A contract was made with Carl Zeiss & Co. to supply 330 7 by 50 Zeiss binoculars. Ten surveying sextants fitted with Willson bubble telescopes were issued to the service for trial and report. All navigational allowance lists were revised, new forms printed and issued. The new allowance lists conform to the Navy nomenclature for classification of ships. In this revision the number of allowance lists were reduced from 36 to 16. Forms N. Nav. 164 and N. Nav. 165 for reporting navigational material on hand on board ship and at navy yards have also been revised and printed. Chapter III in part F of the Bureau of Navigation Manual relating to navigational instruments was revised. Among other changes, the recent instructions were incorporated in regard to the necessity of regular cleaning of chronometers, which should result in automatic replacement of chronometers in need of cleaning without reference to the bureau.

A physical inventory of all navigational material at the Naval Observatory was started in April and was practically completed at the end of the fiscal year. The stock of material at the observatory was greatly reduced and all excess stock sent to the navy yard, Washington, for storage.

Time service.—Time signals were sent out by the Naval Observatory via several radio stations, as shown in the following table. The radio stations listed are operated automatically from the Naval Observatory by telegraphic control lines. In addition to the radio service listed below, the noon signals, and to some extent those at 10 p. m., seventy-fifth meridian time, were distributed by the Western Union and Postal Telegraph Cos. to nearly all parts of the United States. A number of privately owned broadcasting stations not shown in the accompanying table automatically repeated the Naval Observatory time signals, either by means of telegraphic control lines or by reradiation. All the radio stations listed are property of the United States Navy.

Call	Location	K. C.	W. L.	Kind	Type of signal	Signal G. C. T.	Ending at 75 M.	Dates
NAA.	Arlington, Va.	113	2,650	Mod.	Ord.	3 hours	10 p. m.	Throughout year.
						17 hours	Noon	Do.
		30.6	9,810	C. W.	Ord.	do	do	July 26, 1926.
		36.0	8,880	C. W.	Ord.	do	do	July 12, 1926; Feb. 22 and 23, 1927.
		690	435	Mod.	Ord.	3 hours	10 p. m.	Throughout year.
						17 hours	Noon	Do.
		4,015	74.5	Mod.	Ord.	3 hours	10 p. m.	Mar. 30 to end of year.
NSS.	Annapolis, Md.	17.5	17,145	C. W.	Ord.	do	do	July 1, 1926, to Mar. 26, 1927, 3 hours, inclusive.
						17 hours	Noon	Do.[1]
		17.5	17,145	C. W.	Ver.	3 hours 15 minutes.	10.15 p. m.	Sept. 25 to Nov. 30, 1926, inclusive.
						10 hours 15 minutes.	5.15 a. m.	Do.
						20 hours 15 minutes.	3.15 p. m.	Sept. 24 to Dec. 1, 1926, inclusive.
		17.6	17,045	C. W.	Ord.	3 hours	10 p. m.	Mar. 27 to July 1, 1927, inclusive.
						17 hours	Noon	Mar. 26 to July 1, 1927, inclusive.[1]
NKF.	Bellevue, D. C.	4,015	74.7	Mod.	Ord.	3 hours	10 p. m.	December, 1926, to Mar. 29, 1927, inclusive.[2]
						5 hours	Midnight.	Dec. 30, 1926, to Jan. 7, 1927, inclusive.
		4,015	74.7	Mod.	Ver.	3 hours 25 minutes.	10.25 p. m.	Sept. 25 to Nov. 30, 1926, inclusive.
						10 hours 25 minutes.	5.25 a. m.	Do.
						20 hours 25 minutes.	3.25 p. m.	Sept. 24 to Dec. 1, 1926, inclusive.
		12,045	24.9	Mod.	Ver.	3 hours 25 minutes.	10.25 p. m.	Sept. 25 to Nov. 30, 1926, inclusive.
						10 hours 25 minutes.	5.25 a. m.	Do.
						20 hours 25 minutes.	3.25 p. m.	Sept. 24 to Dec. 1, 1926, inclusive.
NPL.	San Diego, Calif.	30.6	9,810	C. W.	Ord.	17 hours	Noon	Throughout year.
		102	2,940	Mod.	Ord.	do	do	Do.
NAR.	Key West, Fla.	102	2,940	Mod.	Ord.	do	do	Do.

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[1] N.A.A. sent a few signals for N. S. S. as noted above.

[2] N. K. F. sent a few signals in December, 1926, and regularly after Jan. 1 1927.

K. C.=Frequency in kilocycles. W. L.=Wave length in meters. Ord.=Ordinary. Ver.=Vernier. G. C. T.=Greenwich civil time. 75 M.=Seventy-fifth meridian time.

The signals marked vernier code consisted of 61 beats to every mean time minute and were sent for use in the world longitude determination. Those sent previous to October 2, 1926, were used for practice purposes only.

The short-wave signals sent via Bellevue and later via Arlington were found very popular owing to the fact that they could be received with simple apparatus. It is expected that beginning August 1, 1927, all time signals will be sent on 8,030 kilocycles (37.4 meters) and 12,015 kilocycles (24.9 meters), as well as on the previous frequency of 4,015 kilocycles (74.7 meters). This should make the short-wave signals available over a very wide territory.

Excepting Key West and San Diego, the radio stations listed in the foregoing table were usually automatically recorded at the Naval Observatory and their lags determined. Owing to the length of the telegraphic control lines operating the Key West and San Diego stations, the time signals emitted by them lag a considerable fraction of a second (Key West about 0.25 second and San Diego about 0.5 second) and are therefore not of high precision for scientific uses, but are satisfactory for navigation and commerce.

The signals sent out at 3 hours January 28 and at 17 hours March 8, 1927, were accidentally about 1 second late. Excepting these signals, the maximum error of any signal was 0.15 second, and the average error was 0.031 second.

In addition to the automatic reception of the Bordeaux, France, radio station signals a large number of records of distant radio stations were made during October and November, 1926, in connection with the world longitude determination. During this period radio apparatus designed in the time service was used at San Diego, where automatic records were also made.

Chronometers, torpedo-boat and patrol-boat watches, patrol-boat chronometers, comparing and stop watches, and clocks.—One trial, for old chronometers only, was held during the year, beginning January 11 and ending June 20, 1927. The date for chronometers making a trial number of less than 35 is given in a table to be found elsewhere in this report.

The following timepieces were received during the year:

Chronometers, old:	
For trial	233
For repairs	118
Torpedo and patrol boat watches and patrol-boat chronometers, old:	
For test	298
For repair	120
Comparing and stop watches, old, for test	298
Deck, boat, airplane, and wall clocks, for test:	
New	264
Old	744

All timepieces except chronometers, torpedo and patrol boat watches, and patrol boat chronometers were turned over to the supply officer for stock after test. The following were issued during the year by the time service:

Chronometers, for use	124
Torpedo and patrol boat watches and patrol-boat chronometers, for use	146

SUPPLY DIVISION

[L. Neely, assistant to the supply officer]

Value of stock on hand July 1, 1926	$2,080,442.88
Value of instruments, etc.:	
Purchased	92,278.19
From stations and ships	165,793.14
	2,338,514.21
Issued and expended	1,406,979.35
Value of stock on hand, June 30, 1927	931,534.86

	Navigational	Aeronautical	Total this year	Total last year
Shipments received	1,284	189	1,473	1,469
Instruments and parts received	37,220	49,203	86,423	47,920
Shipments made	1,262	472	1,734	1,523
Instruments and parts shipped	18,924	20,595	39,519	29,673

The clerical force of the supply division has remained intact and unchanged during the fiscal year. This circumstance, together with the increase in the force of one clerk toward the end of the previous year, has operated to increase the effectiveness of the force in the accounting and routing of the office, in their current work, and in meeting the requirements of the Bureau of Supplies and Accounts in regard to prompt rendition of returns—this in spite of the antiquated methods of accounting employed in the office. Current work has fully occupied the force so that time for a physical inventory, a proper accounting for and disposal of a mass of material that accumulated here after the late war, has been out of the question without paralyzing the current activities of the institution for months. The accumulation of material was due to the large number of ships decommissioned after the war, delivery after the war of material contracted for during the war, and delivery of material of incompleted contracts after the war.

To correct this condition arrangements were made with the Bureau of Supplies and Accounts whereby the temporary services of a supply officer with a small clerical staff and several laborers have been secured to go over the situation, dispose of the material to the best advantage to the Government, and institute a modern system of accounting.

INSPECTION DIVISION

[Commander Harry Kimmell, United States Navy (retired), in charge]

Not many new instruments have been purchased except in aviation. Six-power prismatic binoculars have been reconditioned at the Washington Navy Yard and 7-power Zeiss binoculars purchased for the fleet. The shopwork has been going on steadily with increase in aviation and experimental work. Much material has been purchased for repair work and repair ships.

The following is a list of navigational and surveying instruments repaired during the year:

Alidades	4
Azimuth circles	77
Barometers	62
Bearing circles	14
Binoculars	252
Chronometers	57
Chronometer boxes	75
Clocks	667
Compasses	251
Dividers, spacing	5
Horizons, artificial	17
Magnets	63
Magnetometers	5
Mirrors, resilvered	449
Peloruses	5
Protractors	37
Sextants	141
Spyglasses	182
Stadimeters	9
Telescopes, ship's	10
Thermometers	10
Transits	8
Universal drafting machines	37
Watches	329
Miscellaneous	259
Total	3,025

The following is a list of aeronautical and aerological instruments repaired:

Aerographs	5
Altigraphs	9
Altimeters	453
Anemobiographs	9
Barographs	14
Bearing plates	25
Chart boards	5
Clocks	69
Compasses	357
Drift angle meter	10
Hydrographs	32
Sextants	10
Theodolites	3
Thermographs	7
Miscellaneous	17
Total	1,025
Grand total	4,050

Cost of repairs, grand total, $30,364.50.

DEPARTMENT OF NAUTICAL ALMANAC

[Capt. W. S. Eichelberger (Math.), United States Navy, director]

The almanac office lost by death on January 25, 1927, one of its most valuable assistants, Associate Astronomer Arthur Newton, who had been connected with the office since 1904.

The investigation of the orbits of Saturn's satellites has been continued. One hundred and seventy-eight sets of corrections to the elements have been obtained from 18 pairs of satellites and equations of condition have been formed for 17 more sets, covering in all 22 oppositions. There have been received during the year in manuscript through the kindness of Prof. E. B. Frost, director of the Yerkes Observatory, the results of Professor Barnard's observations during the years 1917–1922.

Work has been commenced on a new zodiacal catalogue to contain over 3,000 stars, including all those in Hedrick's Zodiacal Catalogue and in Gill's Catalogue of 2,798 Zodiacal Stars.

DEPARTMENT OF ASTRONOMICAL OBSERVATIONS

DIVISION OF THE PHOTOGRAPHIC ZENITH TUBE AND ALT-AZIMUTH

[Capt. F. B. Littell (Math.), United States Navy, in charge]

PHOTOGRAPHIC ZENITH TUBE

During the absence of Captain Littell on the world longitude work in California Astronomer G. A. Hill was in charge of this division. The number of observations secured during the year was 1,850.

ALT-AZIMUTH

On account of the accumulation of reduction work in the observatory, it has been deemed advisable to omit observations with this instrument during the year.

DIVISION OF THE EQUATORIALS

[Commander Asaph Hall (Math.), United States Navy (retired), in charge]

26-INCH EQUATORIAL

Observations were made as follows:

Occultations	25	Comet 1927d (Stearns)	7
Eclipses of Jupiter's satellites	5	Satellites of Mars	95
Comet 1926f (Comas Sola)	4	Satellites of Jupiter	3
Comet 1927c (Pons-Winnecke)	8	Satellites of Saturn	38

Determinations of the following were also made:

Instrumental constants	3
Parallels	98
Coincidences	20

The screw of the Repsold micrometer of the 26-inch was examined. The errors remain negligible. This micrometer was removed from the instrument and cleaned, and a new set of spider threads was inserted.

The setting dial of the 26-inch was removed and the parts connected with it were cleaned. The face was resilvered, and a new clock work was mounted inside the box to drive the dial and read sidereal time.

Six new positive eyepieces, low and medium powers, were purchased for the 26-inch. Four new bevel gears and two driving rods were bought for this instrument, these to take the place of the gears and rods which go from the driving clock inside the pier to the worm screw moving the large driving wheel centered on the polar axis.

12-INCH EQUATORIAL

With this instrument were observed 17 occultations of stars by the moon and 3 eclipses of Jupiter's satellites. Also, there were made 2 determinations of instrumental constants.

The observatory was open to visitors by card for viewing the heavens through the 12-inch telescope on 78 nights, of which 22 were cloudy. There were 2,370 visitors, including those received on special nights assigned to schools.

A friction drag was mounted on the 12-inch driving clock, to control the conical pendulum, taking the place of the break-shoe control.

PHOTOGRAPHIC TELESCOPE

On account of the pressure of other work no observations have been made with this instrument during the fiscal year.

THE PHOTOHELIOGRAPH

Observations of the sun with the photoheliograph were made on 247 days. Solar spots or groups were observed on 244 of these days.

Several enormous groups have appeared during this period. Solar activity is still increasing as denoted by the number and size of spots, indicating a probable maximum during 1928.

As usual, data by post card have been furnished the Western Union Telegraph Co. as to the current solar record. An increasing number of magnetic disturbances will probably occur with the increase in solar activity.

The current solar photographs have been measured for position and area of spots.

Beginning with January, 1927, the current solar observations have been published in the Monthly Weather Review of the Weather Bureau, United States Department of Agriculture. In order to render this published record as complete as possible any daily solar observations missing at the Naval Observatory are obtained, if practicable, through the cooperation of the Harvard College, Yerkes, or Mount Wilson observatories.

The shutter of the photoheliograph has been improved by the addition of starting springs to increase its speed. An air-cushion device has also been installed to check the shutter's momentum gradually after the photographic exposure.

A diaphragm of 4 inches aperture has been provided to slip readily over the cell of the 5-inch objective. This is used to cut down the light of the solar image on bright days to avoid narrowing the shutter slit excessively. No loss of finer solar detail is apparent with this 20 per cent reduction in aperture.

An equatorial volume has been completed and has been approved by the executive committee for publication.

This volume, Volume XII, contains observations made with the 26-inch and 12-inch equatorials during the period 1908–1926, inclusive, except the observations of the Mars' satellites taken in 1926. Also, there are included about 750 asteroid observations secured with the photographic equatorial during the years 1912–1924, and measures of the sun plates made with the photoheliograph during the years 1921–1926.

A few observations taken before 1908 and not printed in the preceding equatorial volume are printed in this one.

This volume includes, also, discussions of a number of series of satellite observations; namely, satellites of Mars, Saturn, Uranus, and satellite of Neptune.

DIVISION OF THE PRIME VERTICAL TRANSIT

[Astronomer George A. Hill, in charge]

Work has been continued in the reduction of the observations which have been secured with the instrument. That has consisted in the determination of the observed declinations of the stars and also their reduction from apparent to mean place. No observations were made during the year due to the necessity of completing the above work.

Some very favorable comments on the Prime Vertical Volume have been received.

This division has been engaged in instructing naval officers of junior rank in the methods of using both an engineer's transit and a combined transit and zenith telescope. These special duties are to be carried out under the direction of the Hydrographic Office and in connection with the surveys it is now having made.

During the year 12 officers were given instructions in the duties above specified. One of that number, in addition, received special instructions in the use of the transit and zenith telescope, which covered a period of six weeks.

At the request of the commanding officer of the survey ship engaged in the above work there have been prepared for the observers, first, four lists of time stars to be used in securing the true time at each station; and, second, about eight pairs of stars for each station with which the latitude of the site of each will be determined. The time list and latitude of stars for the first station have been forwarded.

DIVISION OF 6-INCH TRANSIT CIRCLE

[Astronomer J. C. Hammond, in charge]

Observations of the sun, moon, and planets were continued through the year, the number of observations being as follows:

	6-inch	Prin
Sun	139	
Moon	98	
Mercury	71	
Venus	73	
Mars	19	
Jupiter	16	
Saturn	17	
Uranus	15	
Neptune	13	
Clock stars	2,092	406
Azimuth stars	233	71
Miscellaneous stars	963	
Total	3,749	477

In August, 1926, the contact of the Prin transit (No. 2) was changed so as to operate as a break instead of a make circuit. This makes it unnecessary to have a relay between the micrometer and the chronograph. Observations for time were made with this Prin transit on 45 nights in October and November, 1926, for use in the world longitude determinations.

Observations of list 1 of the Eros comparison stars for the opposition 1930–31, given in A. N. 5375, were begun in January, 1927. All but 7 stars of the 419 in the list were observed twice each, these 7 being too faint for observation. In addition to these, 65 stars in list 2 of the Eros stars, given in A. N. 5403, were observed twice each, time not permitting the observation of more stars in this list. These stars will be observed again in 1928.

The instrument was reversed 28 times and the number of determinations of its instrumental constants is:

Collimation	348	Marks	537
Level	537	Nadir	611

CLOCK VAULT

The temperature in the clock vault was maintained practically constant at 84° F. during the year. Riefler clock No. 60 was used as the standard clock.

The following table gives the mean daily rates of the three Riefler clocks in the vault and the maximum variations in the rates for each month:

Month	No. 60		No. 70		No. 151	
	Mean daily rate	Maximum variation	Mean daily rate	Maximum variation	Mean daily rate	Maximum variation
1926	*Second*	*Second*	*Second*	*Second*	*Second*	*Second*
July	+0.04	0.02	−0.13	0.04	−0.04	0.01
August	+.04	.02	−.14	.04	−.18	.06
September	+.04	.02	−.10	.03	−.21	.03
October	+.05	.01	−.11	.04	−.23	.02
November	+.04	.02	−.10	.04	−.24	.02
December	+.07	.05	−.10	.11	−.22	.01
1927						
January	+.07	.02	−.07	.03	−.24	.03
February	+.06	.02	−.07	.02	−.28	.05
March	+.04	.01	−.09	.03	−.31	.02
April	+.04	.01	−.10	.02	−.33	.02
May	+.02	.02	−.13	.03	−.35	.02
June	+.02	.02	−.13	.07	−.33	.03

Total variation in daily rate during the year:

	Second
No. 60	0.08
No. 70	.10
No. 151	.22

DIVISION OF THE 9-INCH TRANSIT CIRCLE

[Astronomer Herbert R. Morgan, in charge]

The work of this division consists in the reduction of the observations of the intermediary and standard stars and of the sun, moon, and planets made with this instrument from 1913 to 1926. The instrumental constants and the clock corrections are all reduced. The apparent places are reduced as far as 1922 and the mean places as far as 1919. The observations of the moon have been compared with tabular places; the reflection observations are being reduced; the scale value of the screen system determined; the irregularity of the pivots measured; some work has been done on the precessions; and other investigations and discussions are under way. The routine reductions are proceeding slowly. The instrument is not in use, but is being overhauled.

COMPUTING DIVISION

[Under the direction of the executive committee and of Associate Astronomer Eleanor A. Lamson, supervisor]

For the 9-inch transit circle.—Work has been done on the right ascension and declination reductions for the period September, 1921, to April, 1922; also on the reduction of special lists of zenith stars for 1921, 1922, 1924, and 1925, together with the mean place reduction of these stars.

For the equatorials.—Work has been done in preparing for the printer material which is to be included in Volume XII, Publications of the United States Naval Observatory, second series. This included computations of corrections to the elements of the orbits of the satellites of Mars, opposition 1924, the assembly and discussion of asteroids observed with the photoequatorial, and the measuring of the positions and areas of spots and groups on the sun plates taken with the photoheliograph.

For the 6-inch transit circle.—Work has been done on the right ascension and declination reductions for the period May, 1926, to January, 1927.

LIBRARY

Mr. W. D. Horigan[3] continued as librarian throughout the year.

	Volumes	Pamphlets	Total
Contents of the library July 1, 1926	32,868	6,408	39,276
Accessions:			
By purchase	325	0	325
Through exchange	483	129	612
Total[1]	33,676	6,537	40,213

[1] These include books, etc., in 27 languages.

There were distributed 8,344 publications of the institution, including 691 copies of the American Ephemeris and Nautical Almanac for 1927 and 2,269 copies of the American Nautical Almanac for 1927.

CONTRIBUTIONS ON ASTRONOMICAL SUBJECTS BY MEMBERS OF THE NAVAL OBSERVATORY STAFF

In the Astronomical Journal:

1. Observations of Asteroids, by George H. Peters. (No. 865.)
2. Correlation of Winds and Determinations of Longitudes, by John E. Willis. (No. 872.)
3. Observations of the Satellites of Mars, by Asaph Hall, Ernest C. Bower, and discussion by Hall, Bower, and Miss Lamson. (No. 873.)
4. Elements and Ephemeris of 1908 EKa, by Ernest C. Bower and Walter C. Myers. (No. 873.)
5. Variation of Latitude at the United States Naval Observatory, by F. B. Littell, United States Navy. (No. 875.)
6. Observations of Comets Orkisz, Borrelly, Van Biesbroeck, and Blathwayt, by H. E. Burton. (No. 875.)
7. Observations of Satellite VI of Jupiter, by H. E. Burton. (No. 877.)
8. Observations of Occultations during 1926, by Asaph Hall and H. E. Burton. (No. 878.)
9. Observations of the Moon during 1926, by J. C. Hammond and C. B. Watts. (No. 880.)
10. Observations of Comets Van Biesbroeck, Comas Sola, Pons-Winnecke, and Stearns, by H. E. Burton. (Not yet published.)

In other publications and in lectures.

Contributions by Edwin T. Pollock:

"The United States Naval Observatory, Its Functions With Special Reference to Time." United States Naval Institute Proceedings, July, 1926.

The United States Naval Observatory. The Military Engineer, July, 1926.

Annual Report of the United States Naval Observatory. Popular Astronomy, February, 1927.

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[3] He died July 4, 1927, after 42 years' service in the library, which was built up largely through his efforts, and in which his services were invaluable.

Important Advances in Astronomy Which May Occur in 1927. Popu Science Monthly, January, 1927.

The Zero Mark of the United States. (Is Your Yard Yours?) Popu Science Monthly, May, 1927.

Sun Time, Star Time, or Standard Time. Radio talk under auspices Science Service, April 12, 1927.

The Meridian of Washington Relocated. Scientific American, Septem 1927; Washington Post, May 8, 1927; Union Register, June 8, 1927.

When Will a Comet Hit the Earth? San Francisco Chronicle, May Cleveland Plain Dealer, May 29; Toledo Blade, June 17; Union Regis June 15; Brooklyn Eagle, June, 1927.

By others:

New Tables of Natural Cosines and Sines. Before American Astronom Society at Philadelphia, December, 1926, by John E. Willis.

World Longitude Determination. Illustrated lecture before American G physical Union by Capt. F. B. Littell (Math.), April 28, 1927.

Eclipses. Illustrated lecture before Maryland Academy of Science, Ba more, by G. H. Peters, April 25, 1927.

Series of five talks on astronomical subjects before Y. W. C. A., May a June, 1927, by C. B. Watts.

Naval Observatory Eclipse Expedition to Sumatra, 1926, by F. B. Litt Popular Astronomy, August-September, 1926.

BUILDINGS AND GROUNDS

General repairs and upkeep of the buildings, grounds, and roads, together with a routine cleaning and overhauling necessary for the care, preservation, and orderly appearance of a public reservation, has taxed the capacity of the small force available for the purpose to the utmost, with results that can only be characterized as fair. The limitations in appropriations for the above purposes since the fiscal year 1922 allows for the employment of only four laborers instead of the six of former years, the result being that the necessary work in upkeep is gradually getting ahead of the force available to handle it. Work necessary to be done outside of ordinary routine was renovating one set of astronomers' quarters and at the same time doing some renovation on the quarters adjacent to it. Extensive renovation work was done in the superintendent's quarters and on a section of the roadway.

EDWIN T. POLLOCK.

Approved.
R. H. LEIGH,
Chief of Bureau of Navigation.
July 1, 1927.

38											
39											
40											
41	49	−2.30	−2.01	−2.11	−2.04	--------	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
42	77	−3.09	−2.90	−2.99	−2.79	−2.56	−2.47	−2.51	−2.26	−2.24	−2.24
43	29	−2.09	−1.87	−1.96	−1.84	−1.63	−1.67	−1.69	−1.70	−1.74	−1.57
44	21	−1.26	−1.53	−1.74	−1.93	−1.79	−1.67	−1.84	−1.84	−1.79	−1.66
45	24	+.49	+.33	+.19	+.21	+.17	+.44	+.40	+.46	+.51	+.40
46	87	+1.06	+1.21	+1.13	+1.11	+1.03	+1.13	+1.23	+1.23	+1.14	+1.21
47	16	+3.40	+3.03	+3.04	+2.93	+2.84	+2.89	+2.84	+2.64	+2.76	+2.67
48	29	−.31	−.27	−.49	−.41	−.46	−.50	−.47	−.60	−.73	−.66
49	94	+2.06	+2.19	+2.17	+2.19	+1.87	+1.90	+1.79	+1.93	+1.96	+1.86
50	06	+.14	+.07	−.09	−.24	−.37	−.20	−.44	−.29	−.60	−.46
51	96	−.09	+.06	+.03	+.21	+.26	+.31	+.27	+.21	+.07	−.04
52	66	+.84	+.64	+.29	+.26	+.04	+.13	+.20	+.26	+.23	−.03
53	90	+1.54	+1.90	+1.84	+2.06	+2.26	+2.06	+1.96	+1.74	+1.66	+1.66
54	64	−1.54	−1.50	−1.59	−1.59	−1.37	−1.26	−1.44	−1.57	−1.57	−1.47
55	17	+.26	−.13	−.31	−.41	−.47	−.37	−.39	−.13	−.19	−.14
56	53	+1.50	+1.30	+1.36	+1.24	+1.33	+1.29	+1.29	+1.36	+1.99	+.59
57	51	−3.56	−3.47	−3.59	−3.63	−3.59	−3.61	−3.84	−3.69	−3.71	−3.79
58	00	−1.07	−1.07	−1.30	−1.09	−.96	−.94	−1.00	−.93	−.96	−.93
59	21	−1.01	−.16	−.41	−.14	−.50	−.10	−.10	−.36	−.31	−.20
60	14	−.99	−1.69	−1.50	−1.61	−1.74	−1.86	−1.93	−1.81	−2.01	−2.04
61	24	+.57	+.43	+.30	+.64	+.56	+.73	+.60	+.69	+.69	+.81
62	19	−3.31	−3.10	−3.03	−2.94	−3.01	−2.79	−2.64	−2.60	−2.63	−2.53
63	11	+.24	+.01	−.06	−.29	−.49	−.44	−.56	−.30	−.19	−.26
64	06	−1.03	−1.19	−1.37	−.91	−.79	−.51	−.74	−.60	−.61	−.47
65	27	−1.41	−1.47	−1.63	−1.86	−2.04	−1.77	−1.76	−1.71	−2.06	−1.99
66	31	−1.60	−1.23	−1.31	−1.64	−1.34	−1.30	−1.29	−1.64	−1.33	−1.46
67	51	+ 09	+.06	+.01	+.06	+.23	+.50	+.44	+.69	+.31	+.47
68	94	−.33	−.91	−.90	−.93	−1.00	−.97	−1.06	−1.14	−.97	−.86
69	63	−1.56	−1.37	−1.13	−1.20	−.97	−.60	−.54	−.69	−.13	−1.51
70	74	−.46	−.61	−.67	−.76	−.91	−.67	−.73	−.46	−.57	−.64
71	09	−1.91	−1.83	−1.83	−1.90	−1.81	−1.73	−1.60	−1.53	−1.46	−1.40
72	54	+.80	+.40	+.44	+.94	+1.04	+1.09	+1.04	+1.29	+1.07	+.73
73	96	−1.07	−1.84	−1.56	−1.81	−1.86	−1.89	−2.27	−1.79	−1.81	−1.86
74	59	−3.13	−3.34	−3.30	−3.03	−3.14	−3.00	−3.06	−2.90	−3.07	−3.07
75	29	+.11	−.20	−.10	−.44	−.24	−.16	−.06	+.14	+.01	+.24
76	71	+2.34	+2.46	+1.54	+1.99	+1.40	+1.49	+1.24	+1.87	+1.47	+1.50
77	19	+.14	+.31	+.26	+.19	+.27	+.37	+.14	+.41	+.39	+.44
78	47	−2.44	−2.57	−2.77	−2.86	−2.93	−3.09	−2.86	−3.13	−3.17	−3.37
79	93	+.31	+.04	+.10	+.13	−.17	−.06	−.01	+.26	+.16	+.17
80	99	+2.01	+1.89	+1.93	+2.07	+2.07	+2.36	+2.27	+2.50	+2.41	+2.39
81	49	−.54	−.80	−.69	−.63	−.66	−.36	+.23	−.04	+.03	+.09
82	60	+.20	+.51	+.50	+.86	+1.17	+1.19	+1.01	+1.23	+1.83	+.77
83	44	−1.13	−1.29	−1.30	−1.30	−1.41	−1.39	−1.30	−1.46	−1.40	−1.51
84	76	+3.19	+3.69	+3.44	+3.61	+3.84	+4.29	+4.21	+4.29	+4.54	+4.49
85	54	+.24	+.17	+.04	−.06	−.20	−.47	−.77	−.96	−1.11	−1.13
86	03	+3.16	+1.63	+1.70	+1.67	+1.63	+1.84	+2.03	+1.97	+2.19	+2.13
87	61	−1.09	−1.54	−1.23	−1.14	−1.19	−1.24	−1.06	−1.24	−1.70	−1.36
88	81	−.57	−.24	−.21	−.04	+.21	+.23	+.29	+.27	+.31	+.26
89	67	+2.17	+1.67	+1.51	+1.63	+1.14	+1.16	+1.10	+1.17	+1.16	+1.14
90	00	+.47	+.54	+.66	+.40	+.71	+.64	+.89	+1.23	+1.20	+1.19
91	13	+.73	+.79	+.49	+.66	+.91	+1.59	+1.46	+1.54	+1.61	+1.63
92	70	+1.04	+1.39	+1.43	+1.69	+1.21	+1.07	+1.21	+1.54	+1.60	+1.79
	46	+1.90	+1.91	+2.09	+2.29	+2.24	+2.41	+2.34	+2.53	+2.59	+2.59

UNIV. OF MI

APPENDIX NO. 2 TO ANNUAL REPORT OF THE
CHIEF OF THE BUREAU OF NAVIGATION, 1928

ANNUAL REPORT OF THE
NAVAL OBSERVATORY

FOR THE

FISCAL YEAR 1928

UNITED STATES
GOVERNMENT PRINTING OFFICE
WASHINGTON
1928

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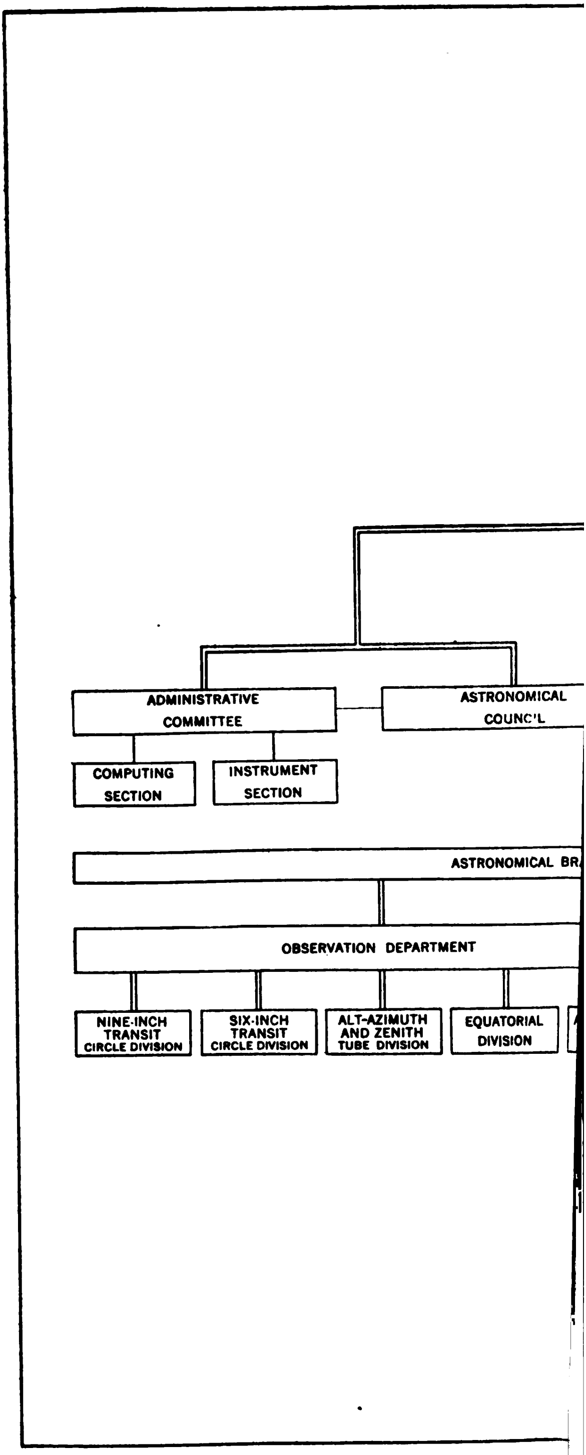

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APPENDIX NO. 2

REPORT OF SUPERINTENDENT OF NAVAL OBSERVATORY

Navy Department,
United States Naval Observatory,
Washington, D. C., July 2, 1928.

From: Superintendent, Naval Observatory.
To: Chief of Bureau of Navigation.
Subject: Report of the Superintendent, Naval Observatory, for the fiscal year ending June 30, 1928.

There is submitted herewith the report on the Naval Observatory for the fiscal year ending June 30, 1928, being the eighty-fourth year of the active operation of this institution and the eighty-sixth since its foundation.

Introduction

Retrospect and prospect.—The year has proved noteworthy, not because of the volume of work turned out, although it has been somewhat above average, due in part to slight personnel increases, but because of a survey of the activities of the observatory by the Bureau of Navigation and a restatement of the functions of the observatory on the part of the Navy Department, which have had the effect of giving greater assurance to the efforts put forth to serve the Nation's fleet afloat, and has inspired with greater confidence the observatory's efforts to serve the general cause of the astronomy of position throughout the world. Like other Government activities which have a public-service function to perform, the observatory feels continuously the increasing demands for its output from a people growing culturally and developing commercially in an unprecedented way. The initial effort in meeting such demands lies always in the direction of adjusting organization and improving administration in a manner to curtail any unessential processes and to eliminate any lost motion that years of routine tend to produce in any working activity. There is a limit to such adjustment and improvement, however, beyond which further progress can be achieved only through increasing expenditures. The justification for such expenditures is found naturally only in increased service for the public good.

Astronomy.—The most important astronomical duties of the Government are the preparation and publication of the American Ephemeris and Nautical Almanac and the derivation and dissemination of correct time. As the data so made public are intended not only for the use of navigators, but also of astronomers, physicists, surveyors, and others, in what may be the most delicate investigations within their respective provinces, these data must be kept up to the highest pitch of accuracy, and should properly be produced in such season as to be available on reasonable demand.

The contacts of the observatory with outside institutions and activities are varied and world-wide. Such contacts are sought and invited, especially along astronomical lines. The motive lies in the fact that research work is not among the main functions of the observatory, but, by means of the research and experimental work carried on in private observatories, they are frequently found to be the best judges of the character of the astronomical investigations the observatory should take up. The principal observational work of the observatory is in the field of the astronomy of position as distinguished from astrophysical work. The programs of work for the various instruments provide for continuous observations of the sun, moon, planets, and fundamental or standard stars for the determination of absolute positions, and provide, in addition, for the conduct of essential contributory observations. Other astronomical investigations of general or special scientific value, either independently or in cooperation with other observatories, are undertaken when the demands of the principal observational work of the observatory admit.

By means of outside contacts therefore, by association with the work of the International Astronomical Union, by the representation of members of the staff in scientific societies, the observatory keeps in close touch with astronomical activity and thus evidences its desire to insure the support and merit the confidence of the best astronomical thought of the world. Meanwhile, by continuous and extended observations, appropriately reduced for use, the observatory seeks to lay up the essential reserve of astronomical material from which may be deduced the ephemerides of the future, as well as to establish a sound foundation of data from which astronomical theories may be resolved into facts and astronomical research may be advanced to discovery.

Until man arrived at some means of finding and tracking his position out of sight of land, deep-sea navigation and hence overseas commerce were impracticable. Position on land is a desirable datum, but great civilizations rose and fell without any very clear conception of position in the world-wide sense. On the other hand, position at sea and out of sight of land is vital and no means, other than by astronomical observations, have ever been devised for establishing such position. It follows, therefore, that the Navy has a primary interest in the astronomical work of the observatory, because deep-sea navigation is impossible except through the agency of astronomical results. In other words, it is by means of the astronomy of position and the data of nautical almanacs resolved therefrom that deep-sea navigation is rendered possible, time is derived, and maritime independence along navigational lines is secured.

However, while the astronomical observations to accomplish these ends are necessarily continuous and unremitting, they have been recognized from the very inception of the observatory as "not sufficient of themselves to give full and constant employment either to the observers or the instruments."[1] The spare time of observers and instruments has, therefore, been used since the observatory's foundation for the advancement of the general science of the astronomy of position, independent of and aside from nautical or naval needs. The American Ephemeris, produced yearly, is more than a maritime handbook; it is definitely a national astronomical volume of the ephemerides of the sun, moon, and planets, of astronomical phenomena, and of valuable tables, employed by astronomers, engineers, meteorologists, physicists, surveyors, and others as a necessary compendium in the carrying on of their work. The derivation and dissemination of accurate time, the answering of astronomical questions which pour in in a steady stream from all sections of the country and, by reference, from many Government activities, the continuous contact and interchange with other observatories, especially foreign ones, the trend of special congressional appropriations throughout the history of the observatory—these and many similar features point to the national status the Naval Observatory early acquired and, in the nature of things, is obliged to maintain.

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[1] First Annual Report; Matthew Fontaine Maury, 1846.

It thus is evident that this institution has a dual character. Basically and primarily the reason for its existence derives from the needs of the Navy, however that reason may be obscured by occasional emphasis laid upon factors in its functioning which are important, but not essential, and by considerations of its possible usefulness based upon the intrinsic worth of knowledge for the sake of knowledge. Inherently then the institution has a naval character, but, as has been pointed out, it has from the beginning functioned as a national observatory and, with the passage of years, has become so invested with that character as to be inseparable from it. The fact that the Navy Department has administered the Government's sole astrometric[2] observatory for more than fourscore years has subjected its administration to the vicissitudes of varied and changeful opinions, but any endeavor to divest it of all astronomical attributes other than those essential to naval or maritime needs would be as futile as an attempt to restrict the invaluable meteorological work of the Weather Bureau under the Department of Agriculture to purely rural necessities. Even as the Weather Bureau ministers to the whole country—the farmer, the aviator, the mariner, the mere pleasure seeker—so the observatory serves not only the navigator and aeronaut, but as well the general astronomer, the engineer, the surveyor, the geodesist, the hydrographer, the geophysicist, the meteorologist, and many another, besides every agency and every individual requiring the provision of accurate time.

However, in rendering such service, the observatory is not permitted to venture far into the fields of abstract research along astronomical lines. Such work is fittingly and properly carried on by nongovernmental observatories. Scientific investigation under Government auspices is habitually restricted to utilitarian objects or to heavy, continuous work which can not find adequate support elsewhere. The astronomical work of the observatory therefore is customarily laborious and is less spectacular than that conceived and pursued at civil observatories, but the results obtained are in large measure fundamental and afford the basis without which the brilliant work of private observatories along investigatory lines would be prolonged and handicapped, if not rendered altogether impracticable.

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[2] Astrometry signifies throughout this report the astronomy of position. Cf. "Astronomy," Russell-Dugan-Stewart, p. 3.

Navigation.—The most important nautical duties of the observatory are the preparation of specifications and allowance lists for navigational equipage and instruments of such a design and character as will secure for the Navy the most reliable and efficient devices procurable for navigational work at sea and in the air; the insurance of an adequate supply and reserve of such material, properly inspected upon receipt; provision for its economical repair and upkeep during service, and of its survey and replacement when obsolete or unfit for use.

A common fallacy, accepted not infrequently by men of high scientific attainments, that navigational instruments have been brought to a perfection which exceeds that necessary for nautical purposes has served to handicap somewhat the research activities essential to the proper development of nautical instruments of precision. The speed of modern ships, their increasing numbers, the keenness of commercial competition, the development of aerial navigation, permit this fallacy no acceptance among present-day mariners. Whereas the demands for exactness of navigation in connection with long-range firing, night deployments without lights, and the maneuvers of submarines and aircraft make it essential that naval vessels of every description shall have the most precise instruments for navigating that it is possible to devise. It is appropriate therefore that the Navy should not only lead in the efficiency of its navigational equipment, but should point the way to the merchant marine along lines of development peculiar to mercantile needs. This essential developmental work and the consequent improvement of navigational instruments compel the observatory to provide for experimental trial of devices which, in the light of study and experience, promise novel results of a desirable character. Such experimental work is especially essential in the field of air navigation, and scarcely less so in connection with gyrocompasses and appurtenant equipage.

Time.—The most immediate contact of the observatory with the general public is through the medium of the time service. The official time signals emanating from the observatory at noon and two hours before midnight, seventy-fifth meridian (eastern standard) time, and broadcasted by the naval radio stations at Arlington, Va., and Annapolis, Md., as well as commercially distributed by the Western Union, Postal Telegraph, and American Telephone and Telegraph systems, and informally by a number of privately owned broadcasting stations, constitute the means for establishing time throughout the United States, for checking chronometers at sea, for longitude determinations in widely separated places in the Western Hemisphere, for gravity determinations in connection with mineral deposits and with geodetic, geological, and geophysical investigations, for the rating of timepieces by clock and watch manufacturers and repairers, and for every purpose for which accurate timing is a principal desideratum. The former practice of giving the correct time over the observatory telephone had to be discontinued in 1926, because the individual requests for that form of time service reached 2,000 per day, and effectually eliminated the possibility of transacting other business by telephone.

This community service to the people of the Nation's Capital was abandoned with regret, but the demands of progress and economy left no other recourse. The growing use of the time service by scientists and the general public has entailed a large increase of work. This condition has been met in part by the assignment of added personnel. Valuable assistance has also been rendered by an officer of the Coast and Geodetic Survey who was temporarily attached to the time-service section during the last three months of the year for the purpose of performing the necessary duties connected with a special 3 a. m. time signal sent out to facilitate geodetic-survey work in the Hawaiian Islands. The details of the regular and special time signals are given under the heading, "Time Service."

FUNCTIONS AND ASTRONOMICAL REQUIREMENTS

The Secretary of the Navy, on December 23, 1927, set forth the following as the mission of the observatory:

> To make such astronomical observations, derive and publish such data, and arrange for the supply of such nautical instruments as will afford to United States naval vessels and aircraft, as well as to all availing themselves thereof, means for safe navigation, including the provision of accurate time, and, while pursuing this primary function, to contribute material, within the capabilities of the available astronomical equipment, to the general advancement of navigation and astronomy.

The mission emphasizes the primary function of the Naval Observatory which concerns itself with the supplying of astronomical data and instrumental equipment adequate to the navigational needs of the Navy, but it stresses also the concomitant function of contributing material to the general advancement of navigation and astronomy.

The scientific work of the observatory, serving at it does both naval needs and astronomical interests, was characterized in the developmental period of the institution by a somewhat varied and irregular output, but experience, criticism, and advice have served to define the institution's field of work in astronomy, and the survey of the observatory's activities and the restatement of its functions, previously referred to as marking the Navy Department's concern with the observatory during the past fiscal year, invite an exposition of what considerations govern its astronomical work. This exposition of the astronomical requirements obligatory on the scientific staff follows under the headings "Field of Work" and "The General Plan."

FIELD OF WORK

> The astronomy of position, contemplating continuous observations of the sun, moon, planets, and fundamental stars for the determination of absolute positions, including the position of the equator and equinox among the stars, and essential contributory observations.
>
> Other astronomical investigations of general or special scientific value, either independently or in cooperation with other observatories, undertaken so far as time, opportunity, and the demands of the principal observational work of the observatory admit.
>
> Preparation and publication of the American Ephemeris and Nautical Almanac, referred to hereafter as the American Ephemeris.
>
> Derivation and dissemination of correct time.

THE GENERAL PLAN

To maintain a continuous series of observations of the sun, moon, planets, and the standard stars of the American Ephemeris in order to contribute a reserve of data for use in preparing the tables of the American Ephemeris, and in order to provide for the determination of such quantities, including the constant of refraction and the variation of latitude, as are essential to the reduction of such observations.

To maintain a series of observations of such stars as may be selected to serve the possible or probable future needs of the American Ephemeris, being guided in such selection by the recommendations of the International Astronomical Union or other widely recognized source of authoritative opinion.

To maintain a regular series of observations of occultations of stars by the moon in order to aid in improving the elements of the moon's orbit.

To maintain a systematic series of observations of the satellites of the planets in order to improve the tables of the satellites in the American Ephemeris, to aid in determining the masses and forms of the planets, and to provide data for the investigation of problems connected with satellite motion.

To maintain a series of observations of asteroids for purposes of record and to employ asteroid observations for parallax and other determinations as may be required in improving the tables of the American Ephemeris.

To conduct observations essential to investigation of the astronometric constants used and published in the American Ephemeris, including the constant of aberration and the obliquity of the ecliptic.

To observe comets sufficiently to establish their probable orbits in order to provide data for their further investigation should such investigation prove desirable.

To observe solar eclipses visible at the observatory and total solar eclipses, when practicable, wherever visible, in order to preserve eclipse data for future astronomical investigations.

To secure sun-spot data, in order to insure the supply of such data to the Weather Bureau and other activities for meteorological and electrical investigations.

To engage, after thorough consideration and deliberation, in such astronomical projects or investigations, exemplified in the past by the work of the Transit of Venus Commission and the observations for world-longitude determination, as may come within the purview of the mission of the observatory and be comprehended in its field of work.

To employ photographic methods in carrying on the observational work of the observatory in all cases where astrographic methods may be found to be applicable and to make such methods primary in securing results whenever the results so attained assure the astrometric accuracy required for computing data employed or which may be employed in formulating the tables of the American Ephemeris.

To give habitual and thoughtful consideration to the latest scientific developments and demands in those activities employing the American Ephemeris and Nautical Almanac, in order to be continuously guided as to the contents of the annual volume.

To insure systematic improvement of the tables of the American Ephemeris by continuous theoretical investigations, by discussions of observations, and by the timely use of the latest approved astronomical results applicable to the revision of such tables.

To provide for a wide broadcasting by radio and telegraph and other approved means of the correct time derived by observations with the highest grade transit instruments available; a study and application of all feasible improvements to the time service; and a comparison, where practicable, of the time results of this observatory with those of other time service agencies, with a view to checking the relative accuracy of the results and acquiring data as to future world-longitude determinations and possible improvements in the radio methods employed therein.

ADMINISTRATION OF ASTRONOMICAL WORK

The astronomical council, established in 1908, continues its valuable work as a part of the administrative system of the observatory. Besides the superintendent and assistant superintendent, the council is at present composed of the head of the ephemeris department, who is the director of the Nautical Almanac, of the five heads of divisions of the observation department, and of the assistant director of the Nautical Almanac. The chief clerk of the observatory acts as recording secretary of the council and custodian of its permanent minutes.

The council meets in regular session monthly, except during August, and holds special meetings at such other times as the superintendent may direct. The monthly reports made by the heads of all unit activities of the observatory, including both the astronomical and nautical branches, are laid before the council at its regular meetings, and hence the scientific personnel of the institution are afforded information of the general work in all departments.

The council advises the superintendent on the following subjects:

(*a*) The coordination of the work of all unit activities of the astronomical branch of the observatory, and the insurance of cooperation between the various activities.

(*b*) Plans, methods of prosecution, and publication of the astronomical work of the observatory.

(*c*) Condition of instrumental equipment and proposed changes therein or repairs thereto.

(*d*) The assignment of all scientific personnel to the unit activities.

(*e*) Promotions, transfers, and filling of vacancies.

(*f*) The annual budget estimates.

(*g*) The expenditure of the appropriations for astronomical and scientific purposes.

Should the superintendent not act on the advice of the council, he gives his reasons therefor and they are entered upon the permanent minutes.

The varying character of the astronomical work performed in the several divisions of the observation department and in the ephemeris department is such that any plan of administration omitting an advisory agency representative of all of the activities would almost certainly tend toward overemphasis upon one or another line of endeavor. Through the agency of the astronomical council, the superintendent is kept informed in a very complete manner of the progress, needs, character, and outlook of the astronomical work, his administrative decisions are guided and his technical decisions largely determined by the advice of representative experts in positional and theoretical astronomy, and a continuity of plan in the astronomical functioning of the observatory is assured in a manner secure from individual predilection or bias. This basic feature of the administration of the astronomical activities of the observatory has proved in its 20 years of application to be increasingly sound and efficient, and lends itself in a remarkable way to the insurance and preservation of continuity in the plan of scientific work, while permitting every proper freedom for the exercise of individual initiative on the part of the leading astronomers of the institution.

ADJUSTMENTS OF ORGANIZATION

The survey of the organization of the observatory which marked the early months of the past fiscal year indicated the basic organization as especially competent and effective. The few adjustments that were deemed necessary were largely along the lines of authenticating current practices which were found to be in the interest of efficiency, but which represented a drift away from the implicit wording of the governing regulations. As noted in the annual report of last year, circumstances had conspired to bring about unsatisfactory conditions in regard to the methods of handling navigational supplies at the observatory. Following a physical inventory of property under the auspices of a supply officer with a small clerical and labor staff temporarily assigned to the institution, the several functions of supply, repair, and inspection of nautical instruments were united in one division of maintenance, under which the repair shop, with its skilled watchmakers and instrument makers, operates with increased efficiency and economy.

As previously indicated, the aim of all adjustments has been the curtailment of unessential processes and the elimination of lost motion in administrative practices, with a view to clearing the way for the increased public service for which there is an ever-increasing demand.

Outstanding Needs of the Observatory

Analysis and comparison indicate most serious omissions in the equipment of the observatory. The difficulty about presenting the case for research, experimentation, and investigation along scientific lines lies, of course, in establishing the value of the results so obtained, in connection with some basic function of Government. Basically, and using the language of the Constitution to frame the thought, the scientific bureaus of the Government "promote the general welfare" of the Nation. The degree to which they promote varies under varying circumstances. The geologic survey of waste land may yield valuable results or it may give no economic return. The National Museum, with its invaluable collections, contributes to national well-being along cultural rather than along commercial lines. The Bureau of Standards, conducting supremely important work, may carry on certain researches that are so closely analogous to work pursued in private industrial research laboratories as to be repetitious and many of its investigations may yield only negative results. It is the same in other scientific bureaus. The invaluable work of the Weather Bureau, for instance, can not in the nature of things produce faultless predictions. So in astronomical work the observations painstakingly obtained often show no immediate results; in fact, are in large measure deliberately laid up for future generations. The standard therefore upon which the equipment of the observatory should be maintained must be sought on some basis other than either a purely naval or a strictly economic one. As a first-class power, the United States should support a first-class observatory. The determination of what is first class is not always simple, but comparison with other national observatories conceded to be fairly well equipped is undoubtedly a guide. Such comparisons bring out the fact that the only astrometric observatory supported by the United States Government does not measure up to other first-class observatories, national or otherwise, in astrographic equipment, and hence falls short of adequately discharging its appropriate scientific function in the Government service.

The need therefore of an astrographic laboratory for the Naval Observatory is imperative, because of the consistent tendency in modern astronomy of the photographic method to supersede eye observations in much of the work of the great observatories of the world. An application for funds for establishing such a laboratory and securing the necessary equipment has accordingly been submitted, and the observatory has been in touch with astronomical experts in the photographic method throughout the country, consulting them as to the most efficient types of instruments and appurtenances.

Other needs not so immediately pressing are indicated by the age of the instruments and the lack of modernity in the design of the structures housing them. The lenses of the objective of the 26-inch equatorial have always contained bubbles and numerous bits of pot metal. They are both strongly colored, the crown being decidedly greenish due to iron impurities, while the flint is strongly yellow. The demand for an expansion of the astrographic work of the observatory supersedes, however, all other demands, and it is deemed expedient to secure funds for such expansion and the necessary personnel before emphasizing other scientific desiderata.

There are certain humbler needs that persist in obtruding themselves, in spite of zealous attempts to meet the situation with the funds provided. For many years an annual appropriation of $10,000 was made available for work on the grounds and roads of the observatory. This generous sum was applied to the grading and landscaping and general upkeep of the extensive grounds of the observatory in a manner to make them a public park with some claim to beauty. In 1912 this appropriation was cut in half. In 1919 it was increased to $6,000. Meanwhile the prices of labor and material have advanced practically continuously, with the result that the grounds and roads of the observatory are suffering a gradual deterioration, and so much so that actual complaints have been made that the observatory is harboring a fire risk in one part of the reservation that is somewhat thickly wooded and contains considerable underbrush. Since the radical cut in this appropriation, the city of Washington has been built up in such a way that the observatory property is in the midst of a residential district of exceptional attractiveness. Extensions to the city street known as Observatory Circle, which will eventually surround the reservation outside of the Government property line, have been made without attendant grading of the adjacent observatory grounds. There is a natural reluctance to ask for money for improvements to grounds and roads when more pressing needs are apparent, but a modest annual increase would serve to check the retrograde movement in regard to property upkeep which is only too apparent under existing conditions. It is perhaps well, in this connection, to emphasize from time to time the fact that the keeping up of the grounds of the observatory as a public park, while highly desirable and a thing that every superintendent will heartily recommend, is not essential to the scientific work of the observatory and in that sense is not directly chargeable to the expense of maintaining the institution, as has sometimes been erroneously asserted.

The three standard clocks of the observatory which measure the national time of the United States and govern the time kept in every industrial establishment and in every community of the country are approaching the age where their gradual replacement is in order.

PUBLIC CONTACTS AND GENERAL PROGRESS

Over 2,750 visitors, including numerous groups from schools, have visited the observatory in the past year, mostly after dark for a view of the night skies. An unduly high percentage of cloudy weather on visiting nights—over 20 per cent—reduced the total visiting list considerably. During November the delegates of the International Radiotelegraph Conference were received by the superintendent and the staff of the observatory and given an opportunity to examine in detail the astronomical and industrial equipment. The line course postgraduate students from Annapolis visited the observatory twice during September for purposes of instruction.

Four officers took the magnetic compass course. Seven officers were given instruction with astronomical and surveying instruments preliminary to taking up surveying duty under the Hydrographic Office. Special data for astronomical work on the surveying grounds were prepared and furnished by the observatory.

The calculated results of the world-longitude determination observations made late in 1926 at San Diego, Calif., and Washington, D. C., have been reviewed and passed for publication by the astronomical council and will appear in Volume XII, Publications of the United States Naval Observatory, second series.[3]

During July, 1927, a special list of stars well distributed in declination was observed on the same nights with the 9-inch and 6-inch transit circles, the altazimuth, and one of the Prin transits to test the performance of these instruments. The results were favorable, showing no discrepancies larger than might be expected from such a comparison among instruments presumed to be accurate.

An exhibit has been prepared for the International Ibero-American Exposition to be held at Seville, Spain, beginning in the autumn of 1928, which is designed to show the astronomical and nautical activities of the observatory.

Various contributions and lectures on astronomical subjects, contributed by members of the observatory staff, are enumerated elsewhere.

The furnishing of data regarding daily sun spots for publication in the Monthly Weather Review of the United States Weather Bureau, instituted on January 1, 1927, has been continued, in collaboration with the Harvard, Mount Wilson, and Yerkes Observatories.

The exchange of certain lands and property as between the Naval Observatory and the District of Columbia, authorized by Congress (H. R. 15541) on March 3, 1927, has been executed so far as legal titles are concerned, the deeds for the exchange being duly filed with the recorder of deeds of the District of Columbia on January 16, 1928, to be recorded among the land records. The record title to all of the lands within the circle of a thousand-foot radius from the standard clock room is now therefore in the United States of

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[3] A summary of the results will appear in the Astronomical Journal.

America, as originally provided in congressional joint resolution of August 1, 1894. (28 Stat. L. 588.)

The various publications issued by the observatory during the past fiscal year are listed under the section devoted to the library and associated matters. A serious handicap under which the observatory labors is the delay that attends publication of astronomical results after their computation. The major features of the astronomical work of the observatory represent years of patient and laborious effort, upon which frequently depend not only future ephemerides but also the character of work to be undertaken by other observatories in various parts of the world. So essential are these results to other observers that partial results are frequently published in scientific journals or are issued in manuscript or mimeographed form. When a delay in publication occurs we have a situation somewhat analogous to that which would occur if a survey of an area were completed and the map of it was withheld from publication or if a coast were critically examined and sounded and the sailing directions and charts of the coast were not made public. Delay in the publication of astronomic results causes economic loss to scientists and institutions depending on such results for their further researches or investigations.

The area of totality of the solar eclipse of May, 1928, was so situated in the South Atlantic as to preclude observations. The area of totality of the eclipse of May, 1929, will embrace a part of the Philippine Islands and should be observed under Government auspices if funds can be found for the purpose. The small staff of the observatory suffers considerable setback in current work when any of their number are temporarily detailed on eclipse expeditions, but the importance of collecting and preserving eclipse data is such as to warrant considerable sacrifices of time and money.

The gyrocompass situation in the Navy shows consistent improvement, although definite defects still exist, leaving room for a further improvement that is being rigorously sought after. Negotiations for the purchase of a new type of foreign compass were cut short, due mainly to the impossibility of arranging for the purchase of any but an unusually large number of compasses on an initial order. Two domestic firms, however, have each developed an improved design of gyrocompass, both of which give promise of producing results of superaccuracy. The importance of compass exactness to the problem of fire control in a modern combatant ship can scarcely be overestimated. The development of superaccurate compasses is expensive, not the least part of the expense being the supplying of apparatus for exhaustive and conclusive tests for the purpose of assuring all concerned that there is being obtained what is sought. Once the developmental stage is passed, however, there is no reason why the cost of future installations should differ largely from the cost of present types. From the observatory point of view, the major improvement called for in the gyrocompass situation is the taking of appropriate steps to train future navigators in the mechanical features of gyro design. The electrical features of a gyrocompass installation are simple compared with the mechanical features, whereas the current tendency is to magnify the former at the expense of the latter. A postgraduate course in gyrocompass engineering at the postgraduate school is very much in order, especially in view of the several millions of dollars invested in gyro installations in our fleet.

PERSONNEL

Capt. Edwin T. Pollock, United States Navy, continued as superintendent until September 19, 1927, when he was relieved by Capt. C. S. Freeman, United States Navy.

Capt. Yancy Williams, United States Navy, served briefly as assistant superintendent from July 5 to July 8, 1927, and Lieut. M. F. Schoeffel, United States Navy, continued on duty until August 9, 1927, in connection with aeronautical instruments, his place being taken by Lieut. T. C. Lonnquest, United States Navy, an officer attached to the Bureau of Aeronautics, with additional duties at the observatory.

Capt. Arthur H. Rice, United States Navy, reported for duty as assistant superintendent on September 2, 1927, and became the head of the readjusted material division. Meanwhile Lieut. Commander W. D. Chandler, jr., United States Navy, was detached on July 2, 1927, being relieved by Lieut. Commander D. B. Downer, United States Navy, who had reported for duty at the observatory on May 5, 1927.

Commander Harry Kimmell, United States Navy, retired, who had been retained on active duty for many years as the inspector of navigational material at the observatory, died in office on August 31, 1927.

Commander Irving H. Mayfield, United States Navy, reported for duty in the new assignment of maintenance officer on October 7, 1927.

Commander W. O. Wallace, United States Navy, reported on May 29, 1928, as equipage officer, filling the vacancy created by the detachment of Commander A. G. Stirling, United States Navy, on May 7, 1928.

Chief Electrician E. H. Belknap, United States Navy, reported for duty on March 2, 1928, as an assistant in the compass division, ultimately relieving Chief Electrician C. H. Snovel, United States Navy, who was detached on May 15, 1928.

Lieut. Commander Lawrence Wainwright, United States Navy, relieved Lieut. Commander W. B. Phillips, United States Navy, as inspector of navigational material in New York on November 5, 1927, having reported for that duty on October 7, 1927.

In accordance with a policy of associating certain younger officers of the Navy more closely with the scientific work of the observatory, in order to secure later the benefit of their trained services, there have been assigned to duty here Lieut. M. E. Eaton, United States Navy, reporting on April 12, 1928, and Lieut. H. G. Williams, United States Navy, reporting on June 1, 1928.

Among the astronomical staff, the following changes are noted:

Appointments.—To be junior astronomers: Glen H. Draper and Charlotte Krampe, July 1, 1927; Arta H. Hadfield, February 29, 1928. To be assistant astronomer: Isabel M. Lewis, October 1, 1927.

Promotions.—To be astronomer: George H. Peters, November 1, 1927. To be associate astronomer: John E. Willis, December 16, 1927. To be assistant astronomers: Gerald C. Whittaker, January 16, 1928; Ulrich S. Lyons, February 18, 1928.

Resignations.—As assistant astronomer, James D. Wise, January 20, 1928.

Deaths.—William D. Horigan, librarian, July 4, 1927; Clifford S. Lewis, assistant astronomer, August 21, 1927; George A. Hill, astronomer, August 28, 1927.

The heavy programs of meridian work taken on several years ago by the transit and altazimuth instruments had gradually produced a lag between the observations obtained and the computations completed so great as seriously to handicap the general progress in obtaining the positional data reasonably to be expected in a well-conducted observatory. This critical condition was eased by the authorization to employ 10 additional scientific aides for computing purposes. A slow, but nevertheless gratifying gain in completed results has followed, which should increase considerably as the quota of 10 is filled and the new aides acquire added experience.

After 37 years of faithful service, William Weast, engineer, was honorably retired from the observatory and the Government service, receiving on the eve of his retirement a letter of appreciation from the Secretary of the Navy.

It is to be noted that the losses to the observatory through the deaths of members of the scientific staff, both in the astronomical and nautical branches, have been especially severe during the past year and have served to reduce the work output of the institution to a serious degree. Individual vacancies are filled as rapidly as circumstances permit, but the experienced facility in securing results which was terminated in these deaths is not readily replaceable.

The year closes with three of the leading members of the astronomical staff absent to attend the Third Assembly of the International Astronomical Union at Leyden, Holland, as delegates. One of these delegates has been specially designated to visit several leading European observatories with special reference to viewing their astrographic equipment.

On June 30, 1927, the personnel on duty connected with the various activities of the Naval Observatory numbered 108. They were distributed as indicated in the following table:

Personnel on duty at the Naval Observatory on June 30, 1928

	Classification and numbers				
	Naval	Professional	Clerical	Subprofessional and custodial	Total
Astronomical branch	3	29		10	42
Nautical branch	7	1	4	20	32
Administrative	2		5	27	34
Total	12	30	9	57	108
Vacancies	3	3		6	12

Of the personnel attached to the observatory on June 30, 1928, the following reported for duty during the fiscal year: 7 naval (58 per cent of the 12 listed); 3 professional (10 per cent of the 30 listed); no clerical turnover; 14 subprofessional and custodial (26 per cent of the 57 listed). Of the 108 total personnel, 24 represented the year's accessions, a turnover of slightly more than 22 per cent, with 12 vacancies to be filled at the beginning of the new fiscal year.

MATERIAL DEPARTMENT

The nautical branch of the observatory has experienced a certain measure of readjustment during the past year incident to the changes made desirable as a result of General Order No. 157 of October 20, 1926, and as a result of a modification in the assignment of officers by the Navy Department. The supply functions formerly exercised by the assistant superintendent were combined with the repair and inspection functions in a new division known as the maintenance division. All compass material, both gyro and magnetic, was placed under one officer instead of two as heretofore. Aeronautical material receives immediate supervision in the aeronautical section, with general supervision exercised by the division primarily concerned. The relation of the observatory to the inspectors of navigation material was more clearly delimited.

All changes have had in view the centering of authority for the expenditure of funds or recommendations therefor in as few hands as possible commensurate with efficient administration, the ultimate object being the conservation of funds available for nautical instruments and the effective use of such funds for improving navigational equipment.

EQUIPAGE DIVISION

[Commander W. O. Wallace, United States Navy, head of division]

Equipment section.—The outstanding features of the work connected with nautical instruments has been the consistent effort made to secure the highest grade material and improved precision in these essential aids to navigation. Specifications were revised or original specifications drawn up for comparing watches, 6-power and 7-power binoculars, stadimeters, aneroid and mercurial barometers, drafting machines, taffrail logs, clinometers, manometers, motor-driven sounding machines, sounding wire, navigators' cases, parallel rulers, and rolling rulers.

Instructions were promulgated providing for a new system of issuing navigational material, the system being designed to save transportation costs. The general stock catalogue, as it related to navigational material, was revised, as was Part G of the Bureau of Navigation Manual, relating to nautical instruments. Considerable attention was given to modifying ships' allowance lists, with a view to having their navigational equipment up to date, special pains being taken to reduce the quantity of excess equipment, where such was found to have accumulated. Chronometers were withdrawn from branch hydrographic offices, with few exceptions, improvements in the communication of accurate time making such chronometers unessential. A considerable amount of the material reported sent to the navy yard, Washington, in the last annual report was found to be in excess or obsolete, and has been sold. Reserve navigational material for decommissioned destroyers in Philadelphia, held in the navy yard there, has been inspected by the head of this division and has been found to be in good condition and well looked after.

Work has been continued at the Washington Navy Yard in reconditioning 6-power binoculars. The same yard has completed two experimental telescopes for high-grade sextants and has underway the development of improved types of spyglasses for deck officers and quartermasters and an improved 7-power binocular. Four Davis bubble sextants have been issued to different vessels of the fleet for trial. Preliminary reports indicate that these sextants will require considerable modification and improvement before they will be satisfactory. However, there is a widespread demand for an efficient bubble type sextant and the observatory is attempting to meet this demand.

Time service.—Associate Astronomer Paul Sollenberger has continued as supervisor of the time service. Time signals were sent out by the Naval Observatory via naval radio stations, as shown in the following table. The radio stations listed are operated automatically from the Naval Observatory by telegraph-control lines. In addition to the radio service listed below, the noon signals and to some extent those at 10 p. m., seventy-fifth meridian time, were distributed by the Western Union and Postal Telegraph Co's. to nearly all parts of the United States. A number of privately-owned broadcasting stations not shown in the accompanying table automatically repeated the Naval Observatory time signals, either by means of telegraphic-control lines or by reradiation. On several dates signals were sent out an hour or two hours later than the regular signals, owing to failure of one or more of the radio stations on the regular signals. These isolated signals are not listed below:

Call	Location	K. C.	W. L.	Kind	Signals ending at—		Dates
					G. C. T.	75 M.	
NAA	Arlington, Va.	112	2,678	C. W.	3 hours 17 hours	10 p. m. Noon	July 1, 1927, to May 29, 1928.
		113	2,655	C. W.	3 hours 17 hours	10 p. m. Noon	May 30, 1928, to June 30, 1928.
		690	435	Mod.	3 hours 17 hours	10 p. m. Noon	Throughout year.
		4,015	74.7	Mod.	3 hours 17 hours 8 hours	10 p. m. Noon 3 a. m.	Do. Apr. 5, 1928, to Apr. 13, 1928.
		8,030	37.4	Mod.	3 hours 17 hours 8 hours	10 p. m. Noon 3 a. m.	Aug. 1, 1927, to June 30, 1928. Apr. 5, 1928, to June 30, 1928.
		12,045	24.9	Mod.	3 hours 17 hours	10 p. m. Noon	Aug. 1, 1927, to June 30, 1928.
NSS	Annapolis, Md.	17.6	17,045	C. W.	3 hours 17 hours	10 p. m. Noon	Throughout year.
NPL	San Diego, Calif.	30.6	9,810	C. W.	17 hours	Noon	Do.
		102	2,939	Mod.	17 hours	Noon	
NAR	Key West, Fla.	102	2,939	Mod.	17 hours	Noon	July 1, 1927, to May 26, 1928.
		106	2,828	Mod.	17 hours	Noon	May 27, 1928, to June 30, 1928.

C. W.=Continuous wave.
K. C.=Frequencies in kilocycles.
G. C. T.=Greenwich civil time.
Mod.=Modulated waves.
W. L.=Wave length in meters.
75 M.=Seventy-fifth meridian time.

Owing to the large number of frequencies transmitted it was not usually possible to record all of them at the Naval Observatory. The 17.6-kilocycle signal via Annapolis and the 112 or 113 kilocycle signal via Arlington were always recorded, when possible, and in addition the 4,015-kilocycle signal via Arlington was recorded at 3 hours Greenwich civil time (10 p. m. seventy-fifth meridian time) and the 8,030-kilocycle signal via Arlington was recorded at 8 hours and 17 hours Greenwich civil time (3 a. m. and noon, seventy-fifth meridian time).

Due to accidental causes, the signal at 3 hours on July 30, 1927, was sent out with an error of 0.44 second and the signal at 3 hours on June 17, 1928, was sent out with an error of 0.62 second. Except for these signals the maximum error of any signal was 0.19 second, and the average error was 0.031 second. These errors refer to the times of transmission from the Naval Observatory, and not to the times of emission from the radio stations, which were generally larger.

Beginning with the month of December, 1927, a change was made in the form of the monthly time-signal data sheets. Previously the times of emission from the Naval Observatory had been furnished together with the lags of the radio stations. Since this caused unnecessary computation both at the observatory and by the user the practice was discontinued, and the times of emission from the radio stations furnished directly. Beginning with the month of May, 1928, the complete nutation was subtracted from the corrections to the sidereal clocks for the purpose of computing clock rates, since sidereal time as ordinarily used is not uniform in its rate of flow. The sidereal times given on the monthly time-signal data sheets were of course furnished with the nutation included, but for the benefit of users who might wish to compute more accurate sidereal clock rates, a new column was added giving the amount of the nutation at each signal. A change was also made in the method of computing the mean time corrections, so as to correct a small inaccuracy which has previously existed due to the term of short period in the nutation.

The signal at 8 hours Greenwich civil time (3 a. m., seventy-fifth meridian time) was sent at the request of the United States Coast and Geodetic Survey for use in connection with surveying work in the Hawaiian Islands. Owing to the fact that there is considerable demand for a signal at this hour, an effort is being made to secure sufficient personnel to make this signal permanent.

One trial of old chronometers was held during the year, beginning January 5, 1928, and ending March 22, 1928. The data for chronometers making a trial number less than 35 are given in a table to be found elsewhere in this report.

Chronometers and watches of all types, together with deck, boat, and airplane clocks, and other timepieces, continued to be received for repair and trial, as has been customary. Cheaper grades of timepieces are not given the formerly customary special two weeks test in the time-service section, provided their regulation and rating in the repair shop indicate that the timepieces are well within the allowed tolerances. This practice expedites repair work, saves labor time in the time-service section, and reduces operating costs.

All timepieces, except chronometers, torpedo-boat watches, and patrol-boat chronometers were turned over to the supply officer for stock after test. The following were issued during the year by the time service:

Chronometers, for use	166
Torpedo and patrol-boat watches and patrol-boat chronometers, for use	200

Owing to shortage of personnel during the first part of the fiscal year, no time signals were recorded from foreign stations. Commencing April 12, 1928, and continuing to the end of the year, time signals from Rugby, England, and Bordeaux, France (Lafayette Radio Station) were recorded.

During this fiscal year a new procedure has been instituted for the trial of old chronometers. Heretofore one trial only was held during the year, it being of about six months duration, the chronometers being tested at 10 special temperatures, one week at each temperature with two days for changing from one temperature to another. These temperatures were 90°, 85°, 70°, 55°, 50°, 50°, 55°, 70°, 85°, and 90° F. They were then tested at 10 weeks at ordinary temperatures. During this year the special temperatures were reduced to six, 90°, 72.5°, 55°, 55°, 72.5°, and 90° F., and the chronometers were tested at each temperature for only five days, two days being allowed for changing temperatures. Then they were tested for five weeks at ordinary temperatures. This change was made with a view to speeding up the turnover of chronometers. On the average under the old procedure a chronometer waited for 6 months after receipt to start the test, 6 months for the test, and 6 months again before issuing, thus taking 18 months out of the 4-year period between cleanings when the chronometer was not in service. By having two trials a year the chronometers will be in service for a much longer period between 4-year periods of cleaning.

Aeronautical section.—Chief Aerographer F. G. Williams, United States Navy, is administering this section of the equipage division, and Lieut. T. C. Lonnquest, United States Navy, of the Bureau of Aeronautics, is the liaison officer in the cooperative work constantly being carried on between the observatory and that bureau. In the joint work required, the observatory has continued to conduct experiments and engage in research work in regard to the design, development, and improvement of aeronautical material.

Flight experimentation has been continued with inductor compasses of the Pioneer type. These compasses are not considered to be suitable yet for service use. Five inductor compasses have been delivered by the General Electric Co. and are being flight tested. The Bureau of Standards is continuing development of a brushless inductor compass based upon the principles of the Briggs-Heyl compass.

The modified NS II and NS III compasses have continued to meet the needs of the service. The observatory has nearly completed the modification of 1,000 NS II aero compasses to that of the NS III and these have been issued to the various aviation activities as directed by the Bureau of Aeronautics. A new design aero compass known as the NS IIII has been developed by the Bureau of Aeronautics. Two experimental compasses were constructed at the observatory and found to be very satisfactory in all the ground and flight tests. Contracts have been let for sufficient parts for the assembly of 500 of these new compasses and it is expected that this work will be completed within the next six months. Four Davis bubble-type sextants are being flight tested and as yet the results are not available. An additional two of these sextants have been delivered fitted for use as theodolites for pilot-balloon soundings, and after being tested were found to be very satisfactory. With but slight modifications, the Navy has now on order 15 of the theodolite-design sextants which will be supplied to the various aviation activities having aerological units. Fifteen Willson bubble octants, embodying the improvements found to be advisable, as the result of ground and flight tests, have been delivered and will shortly be given final tests.

During the past year the observatory has been actively engaged in cooperating with the Bureau of Aeronautics in the development of various aerological instruments for aeronautical purposes. Among these were the ceraunograph (static storm recorder) which, after being designed by the Bureau of Aeronautics, was constructed at the observatory with such alterations embodied as were discussed in conference between representatives of the Naval Observatory and the Bureau of Aeronautics. The air-sounding panel is yet in the experimental stage, but it is expected that this instrument will be perfected during the coming year. A current supply unit was developed during the past year and material is now on order for delivery of sufficient parts for the assembly of 25 of these units. Material is now on order and when delivered an experimental metallic pilot-balloon plotting board is to be constructed. The observatory has undertaken the construction of an experimental hand anemometer with wind vane for the Bureau of Aeronautics. During the past year one of the outstanding achievements in special work done by the observatory for the Bureau of Aeronautics was the assembly of three special aerological units to be used in the selection of a suitable lighter-than-air base on the west coast.

Continued experiments with various types of drift indicators and course and distance calculators have been made.

The observatory maintains constant touch with sources of information abroad, in order to obtain the latest knowledge regarding the development of navigational instruments for aircraft outside of the United States.

COMPASS DIVISION

[Lieut. Commander D. B. Downer, United States Navy, head of division]

The year has been marked by the definite merging of the magnetic and gyro compass activities of the observatory into one division under one directive head, with a resultant gain in economy and coordination of administration. The specifications covering gyrocompasses for navigational purposes have been revised, and study and experiment are being directed with a view to deriving appropriate specifications for gyrocompasses suitable not only for navigation, but for the more exacting requirements of fire control as well.

Preparations have been made to ascertain accurately and in detail the complete action of the gyrocompass both ashore and at sea. Heretofore when a gyrocompass was tested ashore it was rolled, pitched, and yawed for 30 minutes, then steadied and the error read. No data have been obtained as to whether the compass departs from the meridian rapidly or slowly. On investigation to determine how the error occurs, it was found that the involuntary yaw which has occurred when rolling and pitching the compass on the Scoresby stand was caused by the axes of the compass being at right angles to the axes of the Scoresby stand. It was found that by turning the compass 90° on the stand that the yaw disappeared when rolling and pitching. The present binnacles will not permit the testing of compasses to a roll greater than 25° on a side in this manner. A course recorder has been contracted for to attach to the Scoresby test stand to show the departure of the compass from the meridian while the stand is being operated, and by its means the rate of change of the error of the compass will be determined.

The investigation of the generated yaw caused by the fact that the axes of the compass and Scoresby stand were not parallel brought out the fact that the axes of the gimbals of the Sperry peloruses were not parallel with axes of the master compass and would introduce an error between the master and pelorus repeater when the ship rolled and pitched. This also brought up the question of whether the gimbals of the compass were properly mounted in the binnacle with relation to the ship. To determine this a contract was let to the Sperry Gyroscope Co. for a sea testing equipment to determine the errors of the compass at sea within a hundredth of a degree. This equipment will also be used to test compasses at sea to determine the ballistic error and if the damping elimination during a turn is satisfactory. It is hoped that tests at sea will be conducted this fall to determine both of these facts.

Contracts have been let for gyro equipment for the following ships of the Navy: Battleships *Nevada* and *Oklahoma*, light cruisers *Salt Lake City*, *Pensacola*, and *No. 26*, submarines *V-5* and *V-6*, destroyers *Case*, *Sharkey*, and *Isherwood*. A contract has been let for 10 dead-reckoning tracer equipments for battleships and light cruisers. A contract has been let for eight self-synchronous alidades for the battleships *Oklahoma* and *Nevada*, and the light cruisers *Salt Lake City* and *Pensacola*.

New installations of old salvaged Sperry Mark II equipments, which have been modernized, have been authorized for the fleet auxiliaries *Arctic*, *Neches*, *Brazos*, *Ramapo*. A Sperry Mark VIII compass was installed aboard the destroyer *Preston* in place of a Sperry Mark VI compass.

Seven modernized Sperry Mark VI compasses have been put in place of old Sperry Mark VI compasses on destroyers. There remain eight of these compasses yet to be replaced.

The modernization of Sperry Mark II compasses was continued during the year, and 13 compasses have been completed.

The gyro repair shops at Norfolk and Puget Sound have been moved to more suitable quarters during the past year.

A new Scoresby stand has been ordered for the navy yard, Puget Sound, so as to be able to test Arma Mark III and IV and Sperry Mark X compasses.

The observatory has conducted experiments with filling standard Navy magnetic compasses with varnolene, a petroleum product, in place of alcohol and water. Two of these compasses are on test.

The use of this liquid permits the use of steel pivots, reducing friction.

A telescope-bearing circle is being developed which should permit the taking of more accurate bearings. The object, compass card, and level are all seen through one eyepiece. By means of prisms fitted on the end of the telescope star azimuths may be obtained.

MAINTENANCE DIVISION

[Commander I. H. Mayfield, United States Navy, head of division]

One of the primary functions of the Naval Observatory is that of arranging for the supply of the nautical instruments required for the Navy. It is a function distinct from the actual acquisition of such material, which is accomplished through the regular supply channels of the service administered by the Bureau of Supplies and Accounts. It has to do not only with insuring that new material is available but that old material is kept in proper repair. The carrying out of this function has involved since the inception of the observatory the procurement of instruments of precision that do not lend themselves to the sometimes casual handling of a stock room or storehouse and the repair of which frequently calls for mechanical ingenuity of an uncommon sort. So long as the needs of the Navy for such equipment continued small certain methods of handling this equipment through the observatory direct continued adequate, but the heavy accessions of material incident to the World War broke down the system and necessitated a change. The beginning of this change was noted in the last annual report.

An officer from the Bureau of Supplies and Accounts with the necessary clerical force and other assistants made a complete and detailed inventory of all instruments and stock on hand and opened a new set of books. A board of officers appointed by the superintendent surveyed the stock during and after the inventory. All instruments and stock determined to be obsolete, beyond economical repair, or having slight naval value were surveyed, appraised, and sent to the Washington Navy Yard for sale. The book value of this material was approximately $417,000. It was appraised at approximately $31,000, and slightly more than $24,000 was realized from the actual sale. In this manner the enormous stock of excess material was disposed of and the remaining stock properly inventoried and stored. A modern system of bookkeeping has been inaugurated and is operating satisfactorily.

Following the above inventory and sale, the former supply, inspection, and repair activities were organized into one division, called the maintenance division, and Commander I. H. Mayfield, United States Navy, who reported for duty on October 7, was placed in charge of the new division.

After a series of conferences with representatives of the Bureau of Supplies and Accounts, it was decided that, except for chronometers and similar timepieces, the observatory would cease to be the source of supply for navigational instruments and equipage. The responsibility for maintaining adequate stocks of navigational material was turned over to the Bureau of Supplies and Accounts. The naval supply depots at Brooklyn and Hampton Roads were made the central distributing points for the entire Naval Establishment. At the close of the year this plan has been in operation for only a few months, but gives promise of being most successful. It accomplishes decentralization and works toward automatic maintenance of stocks in keeping with the demands of the service. By this plan the Bureau of Navigation can control and supervise the purchase and distribution of its material without the detailed and centralized labor of the actual purchase, storage, and distribution.

With the above system in operation, and when the stock of instruments now on hand at the observatory has been repaired, the value of the material carried here will be reduced to the minimum and will consist mainly of chronometers and similar timepieces. The value of stock on hand on June 30 was $450,724.41 as compared to $931,534.86 at the close of last fiscal year.

The repair policy for chronometers was thoroughly studied and it was decided to abandon the plan of doing part of the repairs on outside contract. An additional watchmaker has been employed, and the shop facilities correspondingly increased. Under this policy all chronometers and similar timepieces for the east coast will be repaired and cleaned at the observatory and distributed as required to the various east coast yards and stations for stock and issue. This plan enables the observatory to know the condition of these instruments as they come in for routine cleaning and in addition will mean a saving of approximately $6,000 per year.

Due to the operation of this modified chronometer repair policy no progress has been made in repairing the large stock of clocks on hand. However, these clocks are not urgently needed, as the stock of clocks at the various yards and stations is more than sufficient to meet all probable demands for a considerable period.

Distinct progress has been made in repairing the stock on hand of all navigational instruments, except clocks. As these instruments are repaired they are sent to the Washington Navy Yard, where they are available for distribution to the various yards and stations as required. Except for clocks, repairs on all instruments for decommissioned destroyers at Philadelphia have been completed.

In addition to the routine work on instruments for stock and for ships the repair shop has done work for various bureaus of the Navy Department and other departments of the Government. The following are some of the items completed or now in progress:

(*a*) Repairs and alterations to 1,000 airplane compasses.

(*b*) Manufacture of two airplane compasses of new design from plans furnished by the Bureau of Aeronautics.

(*c*) Repairs to gun camera stop watches for Bureau of Ordnance.

(*d*) Making necessary alterations to instruments and assembling three complete self-contained units for Bureau of Aeronautics which are now in use in making survey of the Pacific coast for suitable locations for lighter-than-air bases.

(*e*) Conversion of 12 Waltham patrol-boat chronometers into second-setting navigational watches.

(*f*) Development, design, and experimental work on various instruments for Bureau of Aeronautics.

(*g*) Repairs to 50 bomb-sight compasses for Bureau of Ordnance.

(*h*) Two standard 7½-inch compasses were filled with varnolene instead of alcohol and sent to the U. S. S. *Florida* for trial.

Summary of work on instruments during the year:

(*a*) Timepieces of all classes and types	972
(*b*) Navigational and surveying instruments	1,806
(*c*) Aviation and aerological instruments	918

Value of stock on hand, July 1, 1927	$931,534.86
Value of instruments, etc., purchases	77,245.73
Value of instruments, etc., from stations and ships	285,064.19
	1,293,844.78
Value of instruments, etc., issued and expended	843,120.37
Value of stock on hand, June 30, 1928	450,724.41

	Navigational	Aeronautical	Total	Total last year
Number of shipments received	2,686	192	2,878	1,473
Number of instruments and parts received	30,994	30,113	61,107	86,423
Number of shipments made	867	458	1,325	1,734
Number of instruments and parts shipped	20,107	19,836	39,943	39,519

Value of instruments purchased and received from stations and ships per fiscal year:

Fiscal year 1925	$260,129.48
Fiscal year 1926	259,103.01
Fiscal year 1927	258,071.33
Fiscal year 1928	362,309.92

Value of instruments issued and expended to stations, ships, etc., per fiscal year:

Fiscal year 1925	$193,467.86
Fiscal year 1926	229,674.33
Fiscal year 1927	[4] 1,406,979.35
Fiscal year 1928	843,120.37

EPHEMERIS DEPARTMENT

About a quarter of a century ago, Prof. Simon Newcomb wrote: "The term 'Nautical Almanac' is an unfortunate misnomer for what is, properly speaking, the 'Astronomical Ephemeris.'" As a matter of fact, the volume referred to has always been known primarily as the American Ephemeris, the remainder of the designation "and Nautical Almanac" being a supplementary title. In 1904, the Nautical Almanac Office, which for 10 years had been located in the observatory grounds under general observatory supervision, was definitely incorporated as an integral part of the observatory organization and has functioned as a department of the organization ever since. In order to emphasize the more inclusive designation that had applied since its inception to the annual volume of this department, the name Ephemeris Department for the administrative designation of the Nautical Almanac Office was approved by the astronomical council and confirmed by the Bureau of Navigation, in connection with the administrative adjustments of the past year.

Reference to the general plan (p. 6) governing the scientific work of the observatory indicates in how many respects the needs of the ephemeris department govern the output of the observation department. This intimate connection between the two departments of the astronomical branch of the observatory is direct and mandatory. The daily duties of the ephemeris department and of the observation department are, in general, distinct from one another, however. The principal function of the ephemeris department is to predict two to three years in advance of their occurrence the events and phenomena which not only does the observatory record upon their actual occurrence but also the navigator employs in his observations and calculations in determining his position at sea. The observations on which the data and predictions of the American Ephemeris and Nautical Almanac are based have not necessarily been made here, although many of them have. The ephemeris department employs in its computations the published transactions of all well-attested observatories, as well as exchanging data direct with certain foreign almanac offices, in accordance with law.

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[4] Includes material transferred, surveyed for sale, and delivered to the navy yard, Washington, D. C., for stock.

The department has continued under the direction of Capt. W. S. Eichelberger, corps of professors of mathematics, United States Navy.

Beginning with the volume of the American Ephemeris for 1931, the sun's longitude will be referred to the mean equinox of the beginning of the year instead of the true equinox of date; the sun's latitude will be given referred to the ecliptic of the beginning of the year and referred to the ecliptic of date; the sun's rectangular coordinates will be referred to the mean equator and equinox of the beginning of the year; the values of the Besselian star numbers will be given, as well as their logarithms; in the computation of eclipses, the longitude of the sun from Newcomb's Tables will be increased 1ʺ5; and in the computation of the elements for the prediction of occultations the mean longitude of the moon from Brown's Tables will be increased 7ʺ0 as has been done in the computation of eclipses for a number of years.

Much work has been done on the new zodiacal catalogue referred to in the last annual report. Dr. H. Paetsch, of Berlin, has kindly furnished to this office the data from the unpublished volumes of the Geschichte des Fixsternhimmels for 1,136 zodiacal stars. These data, together with those for 447 stars from the seven published volumes of the Geschichte have been entered upon cards with a view of obtaining for each of these stars a position corresponding to the positions of Hedrick's Zodiacal Catalogue.

An intercomparison of the positions of the zodiacal stars contained in the following 10 catalogues has been made in order to determine the systematic differences to be used in obtaining a normal position for each of the zodiacal stars approximately at the epoch 1905:

Publications de L'Observatoire Central Nicolas, Série II, Vol. IX.
Greenwich Second Nine-Year Catalogue for 1900.0.
Annals of the Royal Observatory, Edinburgh, Vol. III.
Publications of the Lick Observatory, Vol. X.
Cape General Catalogue, 1900.0.
Astronomische Beobachtungen zu Königsberg, Abteilung 42.
Veröffentlichungen der Sternwarte zu Heidelberg, Band 5:2.
Publications of the U. S. Naval Observatory, Second Series, Vol. IX, Part I.
Through the kindness of the directors, the unpublished catalogues:
  Catalogue of 2,260 Zodiacal Stars observed at Dunsink, 1900, 1901, 1902.
  Catalogue of Zodiacal Stars observed at Cambridge, 1900–1918.

A similar set of normal positions, for the approximate epoch 1915, is being formed for the zodiacal stars of the Backlund-Hough list based upon five published catalogues of the Cape of Good Hope, Greenwich, Paris, Pulkova, and Washington observatories.

Another set of normal positions will be formed from the observations now being made at the Cape and here.

Since the last annual report it has been decided to include in the new catalogue in addition to all the zodiacal stars contained in Hedrick's Catalogue and in Gill's list, all the zodiacal stars in the Harvard photometry of magnitude 7.0 or brighter. These stars are now being selected and will be added to the observing list of the 6-inch transit circle of this observatory.

Considerable progress has been made on the study of the declinations of about 15 catalogues included within the epoch 1880 to 1900, with a view to forming a normal system of declinations for the epoch 1890.

But little work has been done on the investigation of the orbits of Saturn's satellites. Eight sets of corrections to the elements have been obtained, and the computation of the tabular positions for comparison with Barnard's observations 1917–1922 has been commenced.

A reduction in the size of eclipse maps and the omission of the use of colors, employing a white and stippled black impression instead, serves to reduce slightly the cost of producing the American Ephemeris and the Nautical Almanac.

In addition to the head of department, the following were employed on the work of this department during the year: Astronomer James Robertson; Associate Astronomers Arthur Snow, Walter M. Hamilton, George F. Crawley; Assistant Astronomers Janet McWilliam, Hannah F. M. Hedrick, Thomas E. Trott, Perez Fisher, Clifford S. Lewis (to August 21, 1927), Morris Liferock, Isabel M. Lewis; and Junior Astronomers Charles L. Rush, Rudolph J. Joers, Charlotte Krampe, and Glen H. Draper.

OBSERVATION DEPARTMENT

The various programs of work for the major astronomical instruments are governed by the requirements of the general plan of work (p. 6) of the observatory. Much attention has been devoted during the past year to coordinating the work of the various divisions of the observation department in such a way that the several programs shall contribute annually a definite quota of accomplishment toward the carrying out of the general plan, and wherever practicable the programs shall interlock, so that two or more instruments may be employed to a common end, without undesirable duplication of results.

With a view to promoting intelligent coordination and close cooperation in the work of the observation department, the heads of the five divisions have been constituted an administrative committee for insuring a consideration in detail of matters affecting the carrying on of the astronomical work of the department. The duties of this committee are wide and varied. It meets frequently and informally. Its activities result in considered recommendations by those primarily and jointly interested as to the conduct of the observational work of

the observatory. Through its minutes, its work is habitually subject to the review of the astronomical council. Its membership, comprising five technical experts in positional astronomy in its several branches, assures an acquaintanceship with the literature and history of astronomy in general, as well as with the instruments and methods of work at other observatories, and a knowledge of the present state of current phases of astronomical research. Such acquaintanceship and knowledge enable the committee to judge what problems most require attention and how they can be most successfully attacked. The members of the committee are intimately informed of the widely varied qualifications and degrees of efficiency of their assistants, and their close association in an administrative and advisory capacity through the functioning of the committee can not but enable them to combine the work of their divisions in such a manner as to contribute harmoniously to the furtherance of the general plan of work of the observatory.

NINE-INCH TRANSIT CIRCLE DIVISION

[Astronomer Herbert R. Morgan, head of division]

NINE-INCH TRANSIT CIRCLE

Program.—Observations of—

I. Sun, moon, and planets.
II. Selected standard stars (2,440).
III. Selected intermediary stars (7,561).

Purpose.—

I. To secure data for improving the elements of the orbits of the moon and planets; for the determination of the celestial equator, of the equinox, and of the obliquity of the ecliptic.
II. To secure data for improving the positions and proper motions of the standard stars for use in national ephemerides.
III. To secure data for referring to the standard stars the reference stars used in reducing the plates of the photographic chart of the heavens (Carte du Ciel).

Continuity.—The current program, begun in 1913, is now in the reduction and discussion stage, all observations having been completed in 1926.

Work on the reductions of 72,330 observations made with this instrument from 1913 to 1926 has been continued throughout the year. The apparent star places are now nearly reduced for the entire work, and the mean places are reduced to 1920. These results have been collected on the cards for half the work; the precessions to epoch have been computed and the ordinary discussions and investigations are well started. Additional personnel and an additional high-class calculating machine have very considerably increased the output of the division during the past year and promise a reasonably early completion of the work. Meanwhile opportunity is being taken to overhaul the transit circle.

The reductions of over 700 special observations show that there is practically no difference in either right ascension or declination due to the position of the observer head north, or head south when observing in the zenith using a reversing prism eyepiece. The mean differences for four observers are, in R. A. $0\overset{s}{.}01$, and in Decl. $0\overset{''}{.}06$.

On 74 nights numerous lists of stars were observed direct and by reflection, the observations extending from 16° to 69° both north and south of the zenith, and furnishing in all 1,131 differences, R–D. No star was observed direct and reflected on the same night. The observations were reduced, using the flexure determined from measures on the horizontal and vertical collimators. The residuals show a correction to the nadir, or a R–D discordance of less than $0\overset{''}{.}1$, and no variation with zenith distance; thus substantiating previous results that the collimator flexures should be used.

The observed magnitudes of the 10,000 stars of the catalogue have been derived using the scale equivalent of the screen system based on a comparison of 20,000 observed magnitudes with the Harvard photometric magnitudes. An absorption of 0.45 mg. (sec z–1), and corrections for the different observers were applied. (See Popular Astronomy, May, 1928, p. 291.)

The tabulation of the differences between night rates and day-to-day rates of the standard clock, on 1,535 nights, shows a small variation of $0\overset{s}{.}0004$ in the hourly rate depending on the hour angle of the moon. (See Popular Astronomy, May, 1928, p. 291.)

Some 10,000 observations in the years 1913–1918 have been discussed for clamp difference, the results showing that when the observations have been corrected for the very small pivot errors there is no clamp difference left in the right ascensions as large as $0\overset{s}{.}01$ sec δ.

The personnel of this division, in addition to its head, consisted of Associate Astronomer Jesse Pawling, Associate Astronomer G. M. Raynsford, to January 31; Assistant Astronomer U. S. Lyons, and Junior Astronomer A. H. Hadfield, from February 28 to May 19. All except the head of division have certain observing duties in other divisions.

SIX-INCH TRANSIT CIRCLE DIVISION

[Astronomer J. C. Hammond, head of division]

SIX-INCH TRANSIT CIRCLE

Program—Observations of—

I. Sun, moon, and planets.
II. Selected zodiacal stars (about 3,500).
III. Selected standard stars (about 2,500).
IV. Selected stars for refraction (about 40).
V. Ceres and Vesta.
VI. Eros at opposition of 1930-31.

Purpose.—

I. To secure data for improving the elements of the moon and planets; for the determination of the celestial equator, of the equinox, and of the obliquity of the ecliptic.
II. To secure data for the preparation of a new catalogue of zodiacal stars.

III. To secure data for improving the positions and proper motions of the standard stars for use in national ephemerides.
IV. To secure data for the determination of the constant of refraction.
V. To secure additional data for determining the position of the equator and the equinox among the stars.
VI. To secure data for the determination of the solar parallax.

Continuity.—The current program, begun in 1928, is planned for approximately six years, and contemplates inclusion of previous observations since 1925 under the first subhead, in the discussion of results. No work under the third and sixth subheads is contemplated until 1930.

Observations of the sun, moon, and planets were continued through the year. The Eros comparison stars, which had been observed twice each, as stated in the last annual report, were reobserved to make a total of four observations for each star. The new program of fundamental work outlined above, comprising in addition to the sun, moon, and planets, about 3,500 zodiacal stars and about 2,500 standard stars, was begun on May 24. The zodiacal stars, which include those in Gill, Hedrick, and the Backlund-Hough lists, and, in addition, all others of magnitude 7.0 or brighter, are to be observed four times each in the first two years, if possible. The standard stars, which include all those in the Eichelberger catalogue of 1,504 standard stars and all in the general provisional list of fundamental stars given in the supplement to the Connaissance des Temps for 1914 which culminate at zenith distances less than 70° or 75°, depending on magnitude, are to be observed eight times each during the following four years.

The number of observations made during the year is as follows:

Sun	155	Neptune	14
Moon	124	Clock stars	2,411
Mercury	60	Azimuth stars	290
Venus	96	Refraction stars	15
Jupiter	16	Eros stars	1,042
Saturn	10	Zodiacal stars	728
Uranus	17		
		Total	4,978

In addition, 177 observations of clock and azimuth stars were made with the 3-inch Prin transit No. 2.

On September 1 circle A was rotated through 55° 14′ to read 275° 40′ on the nadir.

In November the glass contact wheel and contact spring of the micrometer were replaced by the instrument maker with a new wheel and new spring operating as a break instead of a make circuit. This change eliminates the relay which had been used to convert the makes into breaks.

In March an attachment for the south collimator, consisting of an arm with a screw and graduated head for giving a slow motion of rotation to this collimator, was made by the instrument maker for use in determining the inclination of the zenith distance threads of the micrometer.

In March and April the errors of the zenith distance screw were measured with a microscope attached to the eyepiece slide. The results showed that the screw is in good condition with no appreciable errors.

In May the pivot irregularities were measured with the axial microscope with results in good agreement with those of previous measures.

The instrument was reversed 23 times and the number of determinations of its instrumental constants is:

Collimation	382	Azimuth from marks	586
Level	583	Nadir	671

The personnel of this division, in addition to its head, consisted of Associate Astronomers C. B. Watts and J. E. Willis; Assistant Astronomer J. D. Wise, until January 20; Assistant Astronomer G. C. Whittaker, from February 1; and Junior Astronomer A. H. Hadfield from May 21.

CLOCK VAULT

The temperature in the clock vault was maintained practically constant at 84° F. during the year. Riefler No. 60 was used as the standard clock until October 8; Riefler No. 151 from October 8 to January 3; Riefler No. 60 from January 3 to March 21; and Riefler No. 70 from March 21 to the end of the year. Rieflers No. 60 and No. 70 were cleaned and oiled in October. The rates of these clocks were somewhat irregular after cleaning and they were again dismounted in February and March for overhauling and minor adjustments in the escapements.

The following table gives the mean daily rates of the three Riefler clocks in the vault, and the maximum variations in the rates for each month:

	No. 60		No. 70		No. 151	
	Mean daily rate	Maximum variation	Mean daily rate	Maximum variation	Mean daily rate	Maximum variation
1927	*Second*	*Second*	*Second*	*Second*	*Second*	*Second*
July	+0.01	0.03	−0.13	0.03	−0.35	0.06
August	−.01	.02	−.12	.04	−.39	.04
September	.00	.02	.00	.20	−.38	.04
October					−.37	.02
November	+.09	.02			−.36	.04
December	+.08	.03	+.07	.07	−.36	.01
1928						
January	+.04	.04	+.12	.07	−.34	.02
February	.00	.15			−.34	.02
March			+.12	.10	−.32	.05
April			+.07	.03	−.35	.03
May	+.05	.05	+.05	.01	−.38	.02
June	+.02	.02	+.03	.03	−.39	.03

Total variation in daily rate during the year:

No. 151 0^{s}.13

ALTAZIMUTH AND ZENITH TUBE DIVISION

[Capt. F. B. Littell (Math.), United States Navy, head of division]

ALTAZIMUTH

Program.—Observations of declinations of sun, Mercury, Venus, Ceres, Vesta, and selected standard stars.

Purpose.—To secure data for improving declinations of objects observed; for the determination of the constant of refraction; for the determination of the celestial equator, of the equinox, and of the obliquity of the ecliptic.

Continuity.—The current program, begun in 1928, is planned for approximately five years and contemplates inclusion of previous observations in the discussion of results.

The new plan of work for the altazimuth outlined above comprises declination observations of the sun, Mercury, Venus, Ceres, and Vesta, and of the stars of the list in Volume X, Part 1, Astronomical Papers of the American Ephemeris and Nautical Almanac, being observed simultaneously with the 6-inch transit circle. Observations were begun on May 24, 1928, and the following have been secured:

Sun	17
Venus	2
Stars	45

PHOTOGRAPHIC REFLEX ZENITH TUBE

Program.—Observations of zenith distances of eight groups of eight stars each, two groups being observed at any given season.

Purpose.—To determine the variation of latitude at the Naval Observatory, the aberration constant, and eventually the nutation constant.

Continuity.—The current program, begun in 1915, is planned to proceed continuously.

Observations with the zenith tube have been continued as usual. The number of observations secured during the year is 1,912. The results of the observations for the year 1926.0–1927.0 have been published in the Astronomical Journal.

The personnel of the division, in addition to its head, has been as follows: Assistant Astronomer G. C. Whittaker, to February 1; Associate Astronomer G. M. Raynsford, from February 1; Assistant Astronomer U. S. Lyons (observing only), to April 1; Associate Astronomer J. Pawling (observing only), from February 1; Junior Astronomer W. M. Browne, from May 21; Junior Astronomer J. D. Phenix (observing only), from June 15.

EQUATORIAL DIVISION

[Commander Asaph Hall (Math.), United States Navy, head of division]

TWENTY-SIX-INCH EQUATORIAL

Program.—Observations of—

I. Positions of satellites.
II. Occultations of stars by the moon.
III. Positions of asteroids and comets.
IV. Eclipses of satellites of Jupiter.

Purpose.—To secure data for the determination and improvement of the elements of the orbits of the observed bodies; the determination of the masses and forms of the planets; the investigation of other problems connected with satellite and asteroid motions; also to supply data for checking the rotation time of the earth.

Continuity.—The current program, begun in 1908, except for the observations of satellite eclipses, which were begun in 1921, is planned to proceed continuously. There has been little change in the observing program for this instrument since its original installation in 1873.

Observations have been made as follows:

Star positions	2	Novas	1
Occultations	31	Satellite VI, Jupiter	3
Comet 1928a (Reinmuth)	1	Satellites of Saturn	27
Eclipses of Jupiter's satellites	6	Satellite of Neptune	14

Value of micrometer screw by arcs, 17; parallels, 62; coincidences, 47.

In August a drag was substituted in place of the brake shoe to improve the action of the governor of the driving clock. In October the Repsold micrometer was removed from the instrument and cleaned and new spider lines were inserted.

TWELVE-INCH EQUATORIAL

Program.—Observations of—

I. Occultations of stars by the moon.
II. Positions of asteroids and bright comets.
III. Eclipses of satellites of Jupiter.

Instrument is also specially used for practice observations and for permitting visitors to view the heavens.

Purpose.—To secure data for correcting the tables of the moon and improving the elements of the moon's orbit; to provide records for determining and improving the orbits of asteroids and comets; also to supply data for checking the rotation time of the earth.

Continuity.—The current program, begun in 1908, except for the observations of satellite eclipses, which were begun in 1921, is planned to proceed continuously, with such modifications as changing methods of securing astronomical data may warrant. The instrument is being employed as an auxiliary rather than a principal instrument of the observatory, and its employment, except in connection with visitors, is intermittent and in lieu of or in addition to the 26-inch equatorial and either under conditions where a smaller equatorial yields the better results or where check observations, as in the case of occultations, are desirable.

During the year, with this instrument, 28 occultations were observed. Also, one observation was made of comet 1927k (Skjellerup) and one observation of an eclipse of a Jupiter satellite.

The observatory was open to visitors by card for viewing the heavens through this instrument on 66 nights, of which 15 were cloudy. There were 2,170 visitors, including those received on special nights assigned to schools.

In May an examination of the screw of the micrometer of this instrument showed the periodic errors to be negligible and the progressive errors to be small.

The division has under way a discussion of the observations of the satellites of Saturn, secured in 1925, 1926, and 1927. A discussion of the observations of the Mars satellites taken in 1926 is nearly completed.

The personnel of the division, in addition to its head, comprises Associate Astronomer H. E. Burton and Junior Astronomer J. D. Phenix.

ASTROGRAPHIC DIVISION

[Astronomer George H. Peters, head of division]

TEN-INCH PHOTOGRAPHIC TELESCOPE

Program.—Observations of—
I. Positions of asteroids.
II. Eros at opposition of 1930–31.
III. Major planets and moon.

Purpose.—
I. To secure data for determining and improving the orbits of asteroids.
II. To secure data for the determination of the solar parallax.
III. To experiment in determining positions differentially.

Continuity.—The current program in respect to asteroids was begun in 1912, similar work having been done with a 6-inch lens since 1903. The remainder of the program was instituted in 1928, and is pursued as opportunity offers, no work being contemplated under the second subhead until 1930. The entire program is planned to proceed continuously.

Observations on this instrument have been suspended since 1924, and one of the 10-inch photographic triple lenses of the instrument was employed on the total solar eclipse expedition to Sumatra in 1926. Needed repairs and improvements, including rigorous readjustment of its pair of photographic objectives, is in progress and will be completed at an early date, when the regular program will be resumed.

Plans have been prepared for a new measuring engine to replace the "Stackpole," which is thoroughly out of date. The new engine will be constructed by the instrument maker of the Naval Observatory on a design of the head of this division. Regular observations with the photographic equatorial will be resumed in the near future.

PHOTOHELIOGRAPH

Program.—Photographs of sun daily.

Purpose.—To secure sun-spot data, in order to insure the supply of such data to the Weather Bureau and other activities for meteorological and magnetic or electrical investigations.

Continuity.—The current program, begun in 1897, is planned to proceed continuously.

Observations of the sun with the photoheliograph were made on 279 days. Solar spots or groups were observed on each of these days. Many enormous groups have appeared during this period. It is likely that a sun-spot maximum will occur the latter part of 1928. Early data regarding sun spots have been furnished by post card as usual to the Western Union Telegraph Co. in New York for use in the study of magnetic disturbances on their lines. In view of the present solar conditions, an increase, both in the number and intensity of magnetic disturbances, is predicted during the coming 12 months.

Publication of current solar observations in the Monthly Weather Review has been continued. For dates missing at the Naval Observatory, data have usually been supplied as heretofore through cooperation of the astronomical laboratory, Harvard College, and the Yerkes and Mount Wilson observatories.

Measures of sun plates taken with the photoheliograph during the years 1917–1920, inclusive, have been completed. These will be incorporated in Volume XII, shortly to be published, which will then include the years 1917–1927. Measures of the current solar plates are completed to date.

The astrographic work of the observatory has been carried on since its inception as an activity under the equatorial division, but with a view to according this work some measure of the importance its character merits and to lay the groundwork for an expansion of the observatory's facilities along astrographic lines, the astrographic division was organized and began functioning as an independent activity on January 1, 1928. One vacancy exists in the division at present, and two additional assistants have been suggested as new apparatus becomes available. Meanwhile one of the staff has been detailed to astrographic research work, in addition to his other duties, and, in addition, a study is being made of the equipment best fitted to assure astrometric results by astrographic methods.

COMPUTING SECTION

[Associate Astronomer Eleanor A. Lamson, supervisor of section]

This activity of the observatory has received a gradual accession of personnel during the year, until at the year's close there were included in the section, in addition to the two professional computers, six subprofessional aides and a prospective accession of four more such aides. This increase in the computing staff has been one of the most valuable incentives to accomplishment that has occurred in the institution in many years, and it has come at a very critical time, when the fundamental work in astronomy was suffering through the inability of the computers to keep reasonably up to date in working up observations. The full benefit of the increase can not be felt until the new personnel has been trained, but some improvement is already noted.

The astronomical council advises as to the policy to be followed in the assignment of computing work and indicates semiannually, in June and December, the distribution of computing personnel desired for the succeeding six months. The administrative committee, consisting of the heads of division of the observation department, attends to the general apportionment of work among the several computers subject to the review of the council. The individual computers may be assigned for limited periods to one or another of the divisions of the observation department for computing work directly under the supervision of the head of division. This has occurred during this past year in respect to the 9-inch transit circle division. Personnel of the computing section not so assigned are under the immediate supervision of the supervisor of the section, who is responsible for their initial training and for the character of their work.

There follows an outline of the general character of the work of the computing section for the past year.

For the 9-inch transit circle division.—Work has been done on the reduction of observations made in the year 1922; also on the mean place reduction of stars observed in 1919 and 1920 and special lists of reflected observations made in the years 1914–1917.

For the 6-inch transit circle division.—Work has been done on the reduction of the observations made during the period January, 1927–June, 1928; also in completing the reduction of observations made in the year 1926. Proof reading of Volume XI, Publications of the United States Naval Observatory, second series, was completed during the fiscal year and the bound volume received at the observatory in January, 1928.

For the equatorial division.—Work has been done in preparing for the printer Volume XII, Publications of the United States Naval Observatory, second series.

For the astrographic division.—The current sun-spot data have been prepared for publication monthly and sent to the Weather Bureau for insertion in the Monthly Weather Review. The printer's copy of the sun-spot material for the years 1917–1927 has also been made and is to appear in Volume XII, Publications of the United States Naval Observatory, second series.

Miscellaneous.—Work has been done on the reduction of 2,500 observations of a list of approximately 820 zenith stars observed with the prime vertical transit during the years 1921–1925.

Work has been done in cataloguing, for convenience of reference, the records of the astronomical work in the archives of the observatory.

LIBRARY

	Volumes	Pamphlets	Total
Contents of the library July 1, 1927	33,676	6,537	40,213
Accessions:			
By purchase	200	0	200
Through exchange	470	524	994
Total	34,346	7,061	41,407

There were distributed 6,463 publications of the institution, including 360 copies of the American Ephemeris and Nautical Almanac for 1928 and 1,568 copies of the American Nautical Almanac for 1928.

A study is in progress to determine the best method of providing for new accessions. Some increase of library space is mandatory, as all present space available is overcrowded.

PUBLICATIONS OF THE OBSERVATORY

Volume XI, Naval Observatory Publications, second series (Six-Inch Transit Circle Observations, 1909–1918), was received from the printer in January, 1928.

Volume XII, Naval Observatory Publications, second series (Equatorial Observations, 1908–1926), has not been published due to lack of funds. Advantage has been taken of the delay to include the Washington-San Diego world longitude determination observations. The volume has again been submitted for publication.

The American Ephemeris for 1930 was received from the printer on April 18, 1928.

The American Nautical Almanac for 1930 is in type and is expected from the printer during the summer of 1928.

The American Ephemeris for 1931 is in the hands of the printer, except for 140 pages, and 234 pages are in type.

CONTRIBUTIONS ON ASTRONOMICAL SUBJECTS

In the Astronomical Journal:

1. Observations of Comets Van Biesbroeck (1925j), Comas Sola (1926f), Pons-Winnecke (1927c), Stearns (1927d), by H. E. Burton. (No. 890.)
2. Observations of Jupiter's Satellite VI, by H. E. Burton. (No. 893.)
3. Variation of Latitude Observations, by F. B. Littell. (No. 895.)
4. Occultations by the Moon, 1927, by A. Hall and H. E. Burton. (No. 902.)
5. Observations of the Moon in 1927, by J. C. Hammond and C. B. Watts, (No. 903.)

In Popular Astronomy:

1. Magnitudes from Transit Circle Observations, by H. R. Morgan and U. S. Lyons. (May, 1928.)
2. Clock Rates and Rotation of the Earth, by H. R. Morgan. (May, 1928.)

Miscellaneous:

A series of monthly articles on various astronomical subjects, by Isabel M. Lewis, published in Nature; also several illustrated articles on astronomy of a popular nature.

Lectures and papers: At University of Florida, December, 1927, by George H. Peters, two illustrated lectures:

1. Dutch East Indies (Solar Eclipses).
2. Sidereal Heavens.

Before American Astronomical Society, New Haven, Conn., December, 1927:

1. Some Results of the World Longitude Work of 1926, by F. B. Littell and J. C. Hammond.
2. Magnitudes for Transit Circle Observations, by H. R. Morgan and U. S. Lyons.
3. Clock Rates and Rotation of the Earth, by H. R. Morgan.

Before Horological Institute of America, May, 1928:

Recent Developments in High Precision Time Pieces, by Paul Sollenberger.

Before Washington Philosophical Society, May, 1928:

Time, by Paul Sollenberger.

UPKEEP

The difficulty of preserving the grounds and roads in a neat and orderly condition with the funds available has been already remarked upon. The buildings also are maintained in only fair condition, although, in general, they are structurally sound. Emergency repairs to the marble balustrade surrounding the dome of the 12-inch equatorial and to about 100 feet of the heating-pipe tunnel have been practically completed, funds having been secured through a deficiency appropriation. Four thousand feet of pointing work has been done on the administration building and the 26-inch equatorial building through a special appropriation. Several major jobs of painting are required for preservation purposes, if funds can be procured, as are grading and clearing to keep abreast of outside private and civic improvements. Meanwhile every effort is being made to hold in check the deterioration that has inevitably resulted from a 40 per cent reduction in the funds which originally established the scale of upkeep deemed proper for the extensive grounds that form the observatory premises.

The consolidation of the observatory's funds, as partly accomplished in the appropriation for 1929 and further recommended for 1930, will serve to benefit the cause of upkeep to a certain extent. Sooner or later, however, a substantial increase in the total amount available for the maintenance of buildings and grounds will become essential, due to cumulative deterioration wholly beyond administrative control or correction in the absence of funds. The desirability of a high degree of upkeep need hardly be stressed. It would be decidedly unbecoming to permit Government property in a conspicuous and rapidly growing residential district of the National Capital to sink in appearance below the level of its surroundings, nor may the effect of surroundings on the working morale of the observatory personnel be wholly disregarded.

C. S. Freeman,
Captain, United States Navy, Superintendent.

Approved August 27, 1928.
R. H. Leigh, *Rear Admiral, U. S. Navy,*
Chief of Bureau.

Data of trial of old chronometers at the United States Naval Observatory, Washington, D. C.

[The signs are astronomical. +losing; −gaining. Data of chronometers with trial numbers greater than 35 omitted]

Order of merit	Temperature ... degrees F Balance: O=ordinary; V=invar; Aux=auxiliary Hairspring: S=steel; P=palladium Chronometer		Kind	Balance hair spring	Trial number	Point of compensation			Mean daily rates										
									Special temperatures						Ordinary temperatures				
									90	72.5	55	55	72.5	90	64	61.9	62.4	63.6	63.8
						Temperature	Rate	Temperature constant	Jan. 5-10	Jan. 12-17	Jan. 20-25	Jan. 25-30	Feb. 2-7	Feb. 9-14	Feb. 16-23	Feb. 23-Mar. 1	Mar. 1-8	Mar. 8-15	Mar. 15-22
1	Bliss	3142	M. T. S.	O. P	1.08	77.5	1.92	+0.00023	−1.90	−1.96	1.82	−1.78	1.80	1.86	2.16	2.21	2.21	2.24	2.30
2	Jensen	76	M. T. S.	V. S.	1.76	62.3	+1.13	−.00020	+.96	+1.00	+1.08	+1.16	+1.22	+1.00	+.97	+.97	+1.09	+1.11	+.97
3	Jensen	75	M. T. S.	V. S	2.00	75.2	+0.06	+.00033	+.10	0.00	+.34	+.04	+.12	+.10	+.03	+.11	+.14	+.01	+.07
4	Johannsen	4676	M. T. S.	O. S	2.33	76.2	2.93	.00011	2.80	2.98	−2.94	3.02	2.88	3.10	−3.00	2.97	3.03	3.06	3.21
5	Bliss	3112	M. T. S.	V. S	2.41	186.4	1.26	+.00006	−.66	.46	.14	−.22	−.44	.70	.10	−.07	−.21	.20	.23
6	Bliss	2059	M. T. S.	O. P.	2.60	138.1	−2.82	+.00013	−2.48	−2.24	−1.90	1.94	−2.28	−2.56	−2.37	2.31	2.27	−2.21	2.33
7	Nardin	1070	M. T. S.	V. S.	2.79	80.8	0.45	.00062	−.52	.58	.82	.90	.40	−.48	.66	.70	−.50	.77	.73
8	Negus	2180	M. T. S.	O. P	2.90	50.1	+0.17	−.00015	−.10	0.00	+.26	+.08	+.20	−.02	−.03	0.00	+.01	+.17	+.19
9	Bliss	3071	M. T. S.	O. P.	2.98	104.2	−1.14	+.00021	1.00	−1.00	0.56	0.70	0.86	1.20	−1.07	1.20	1.11	−1.09	1.13
10	Nardin	1804	M. T. S.	V. S	3.47	69.5	−1.61	−.00119	−2.10	−1.68	−1.82	1.90	1.56	−2.12	−1.81	−1.73	−1.73	−1.81	−1.86
11	Kurtz	110	M. T. S.	V. S.	3.49	72.8	−1.15	+.00057	−.86	−.98	−.90	1.04	1.32	1.10	1.27	−1.23	−1.14	−1.34	−1.24
12	Union	55808	M. T. S.	V. S.	3.50	64.5	−0.77	+.00031	−.40	−.58	−.74	−.80	−.76	−.36	.70	−.81	−.84	−.76	−.53
13	Diedrich	46	M. T. S.	O. S.	3.73	78.5	−3.12	+.00088	−2.86	−3.32	−2.84	−2.80	−2.92	2.90	−3.14	3.03	−3.09	−3.08	−2.97
14	Nardin	661	M. T. S.	V. S	4.70	28.7	−3.18	+.00026	−2.10	−2.80	3.06	2.94	2.56	−2.30	−2.91	2.81	2.80	−2.78	2.81
15	Bliss	3170	M. T. S.	O. P.	4.79	92.7	−0.46	+.00052	−.24	−.28	+.26	+.30	.22	−.58	.11	−.06	+.07	+.14	0.00
16	Negus	1987	Sid	O. P.	4.86	51.9	+1.24	+.00029	+1.84	+1.48	+1.26	+1.22	+1.26	+1.52	+.87	+.82	+.58	+.72	+.70
17	Nardin	2079	M. T. S.	V. S.	5.50	±∞	±∞	.00000	+2.04	+1.46	+1.00	+.94	+1.40	+1.74	+1.29	+1.46	+1.48	+1.29	+1.23
18	Nardin	2058	M. T. S.	V. S.	6.21	−96.9	−18.27	+.00008	−1.58	−2.34	−2.90	−2.82	−2.32	−2.00	−3.10	−3.14	−3.14	−3.11	−3.17
19	Nardin	2065	M. T. S.	V. S.	6.30	73.4	−0.58	−.00124	−.86	−.56	−1.00	−.96	−.56	−.94	−1.00	−.91	−.61	−.54	−.81
20	Kurtz	142	M. T. S.	V. S.	6.47	94.1	−0.93	−.00062	−.86	−1.20	−1.84	−1.92	−1.24	−1.02	1.76	−1.90	−1.60	−1.37	−1.54
21	Bliss	3152	M. T. S.	O. P.	6.68	117.0	−0.90	+.00039	−.42	−.12	+.54	+.68	−.12	.80	+.16	+.13	+.09	+.14	+.13
22	Casseres	870	M. T. S.		7.31	51.8	−1.01	+.00074	+.02	−.76	−.90	−1.10	.60	+.16	−.80	−.80	−.71	−.94	−1.08
23	Negus	2098	M. T. S.	O. S.	7.37	60.0	−1.12	+.00060	−.66	−1.00	−1.06	−1.16	−1.06	−.50	−1.87	−.97	.63	−.97	.89
24	Bliss	3184	M. T. S.	O. P	7.41	76.0	+1.37	−.00086	+1.00	+1.38	+1.00	+.98	+1.34	+1.40	+1.07	+0.86	+0.98	+1.16	+1.34
25	Kurtz	119	M. T. S.	V. S.	7.68	53.2	−0.91	+.00090	+.86	−.68	−.96	−.84	−.48	+.24	.60	−.49	−.41	−.30	−.37
26	Negus	2107	M. T. S.	O. P.	7.71	56.6	+0.44	−.00052	−.10	+.50	+.44	+.44	+.12	−.18	−.17	−.11	−.01	+.18	+.27
27	Nardin	1621	M. T. S.	V. S.	7.77	156.0	+2.81	−.00024	+1.94	+1.14	+.24	+.38	+1.06	+1.54	+.63	+.60	+.46	+.68	+.59
28	Bliss	2807	M. T. S.	Aux. S	7.80	69.9	−1.08	−.00163	−1.56	−1.06	1.38	1.50	1.12	1.92	1.73	1.83	1.86	1.93	−2.08
29	Negus	1094	M. T. S.	O. S.	7.81	71.2	+1.09	+.00214	+1.82	+1.16	+1.70	+1.60	+1.02	+1.86	+1.43	+1.13	+1.39	+1.31	+1.27

30	Tobias	1371	M. T. S		7.87	101.0	-1.02	+.00064	-1.02	-.46	+.34	+.32	-.54	-.86	-.30	-.13	-.37	-.36	-.56
31	Nardin	2067	M. T. S	V. S	8.06	55.1	-1.95	+.00080	-.80	-1.88	-2.04	-1.84	-1.52	-1.14	-2.10	-2.03	-2.03	-2.01	-2.00
32	Hand	[illegible]	M. T. S	Aux. S	8.07	4.4	-4.51	+.00038	-1.72	-2.66	-3.50	-3.60	-2.88	-1.80	-3.57	-3.53	-3.54	-3.43	-3.66
33	Nardin	881	M. T. S	V. S	8.16	-159.3	-8.03	+.00013	+.14	-1.04	-2.08	-1.98	-.98	+.04	-1.69	-1.71	-1.71	-1.64	-1.59
34	Bliss	3085	M. T. S	O. P	8.23	69.5	+0.03	+.00204	+.94	-.02	+.36	+.56	+.12	+.84	+.01	-.09	0.00	-0.03	-.01
35	Nardin	713	Sid	V. S	8.30	66.1	-1.11	+.00049	-.76	-1.32	-1.28	-.82	-.86	-.90	-.93	-1.21	-1.19	-1.05	-1.23
36	Bond	232	M. T. S	O. S	8.45	71.5	+0.30	+.00193	+.92	+.34	+.84	+.80	+.26	+1.00	+.23	+.21	0.00	-.10	-.11
37	Negus	1155	M. T. S	O. S	8.45	65.4	-0.79	+.00174	+.16	-.74	-.60	-.60	-.66	+.38	-.61	-.71	-.77	-.78	-.77
38	Bond	1029	M. T. S	O. S	9.36	71.2	-1.41	+.00218	-.66	-1.46	-.76	-.92	-1.36	-.62	-1.23	-1.27	-1.29	-1.43	-1.54
39	Bond	531	M. T. S	O. S	9.42	69.2	+0.56	+.00220	+1.42	+.60	+1.06	+.94	+.56	+1.60	+.71	+.69	+.70	+.61	+.57
40	Seckel	483	M. T. S	O	9.52	84.5	-3.08	+.00088	-2.74	-3.00	-2.38	-2.24	-2.90	-3.36	-2.81	-2.76	-2.83	-2.64	-2.69
41	Nardin	2073	M. T. S	V. S	9.73	102.2	+1.99	-.00008	+1.90	+1.90	+1.86	+1.76	+1.94	+2.06	+1.64	+1.64	+2.06	+2.24	+2.19
42	Ehrlich	767	M. T. S	O. S	9.82	77.8	-1.11	+.00201	-.96	-1.14	-.02	-.10	-.96	-.66	-.46	-.44	-.41	-.43	-.43
43	Bond	371	M. T. S	O. S	10.12	77.1	-1.48	+.00206	-1.12	-1.38	-.38	-.58	-1.50	-1.16	-1.00	-.94	-.99	-1.21	-1.14
44	Negus	1519	Sid. B. C	O. S	10.14	66.6	-0.72	+.00212	+.38	-.64	-.46	-.42	-.66	+.50	-.47	-.48	-.52	-.57	-.67
45	Bond	570	M. T. S	O. S	10.36	61.2	-1.28	+.00166	-.06	-1.14	-1.18	-1.26	-1.00	+.26	-1.07	-1.00	-1.07	-1.09	-.97
46	Dent	2523	M. T. S	O. S	10.38	70.2	-0.62	+.00225	+.36	-.56	-.08	-.12	-.66	+.16	-.47	-.67	-.81	-.69	-.61
47	Bond	308	M. T. S	O. S	11.20	62.2	-0.84	+.00165	+.40	-.78	-.88	-.62	-.54	+.48	-.33	-.50	-.60	-.57	-.66
48	Negus	1449	M. T. B. C	O. S	11.46	70.9	+0.09	+.00261	+1.10	+.18	+.74	+.76	+.02	+1.00	+.23	+.31	+.20	+.13	+.11
49	Bliss	3018	M. T. S	O. S	11.58	72.2	-0.05	+.00279	+.86	-.10	+.76	+.80	0.00	+.80	+.07	-.11	+.04	-.04	+.06
50	Dent	49456	M. T. S		11.58	112.5	+1.04	-.00023	+.80	+.34	+.14	+.42	+1.00	+1.04	+56	+.27	+.34	+.23	+.20
51	Kurtz	131	M. T. S	V. S	12.03	52.3	-0.81	-.00080	-1.70	-1.00	-.70	-.94	-1.28	-2.20	-1.66	-1.79	-1.96	-1.99	-2.01
52	Bond	512	M. T. S	O. S	12.10	73.5	+0.48	+.00276	+1.18	+.40	+1.44	+1.40	+.56	+1.28	+.83	+.71	+.64	+.64	+.71
53	Negus	1953	M. T. S	O. S	12.24	68.3	+0.58	+.00258	+1.78	+.60	+1.04	+1.04	+.66	+1.82	+.89	+.80	+.86	+.76	+.74
54	Bond	601	M. T. S	O. S	12.38	76.8	+1.07	+.00227	+1.38	+1.24	+2.20	+2.10	+.98	+1.54	+2.07	+2.26	+2.14	+1.91	+2.07
55	Negus	1265	M. T. S	O. S	12.68	67.2	+2.28	+.00238	+3.46	+2.32	+2.52	+2.76	+2.38	+3.58	+2.36	+2.31	+2.23	+2.17	+2.14
56	Nardin	2066	M. T. S	V. S	12.75	41.7	-1.66	+.00111	+.88	-.70	-1.34	-1.60	-.52	+.98	-1.07	-1.21	-1.29	-1.29	-1.34
57	Negus	1812	M. T. S	O. S	12.82	71.4	+0.55	+.00269	+1.40	+.56	+1.38	+1.16	+.54	+1.56	+.77	+.80	+.79	+.61	+.56
58	Bliss	2872	M. T. S	O. S	13.17	62.8	+0.09	-.00222	+1.64	+.28	+.24	+.22	+.32	+1.82	+.16	+.07	0.00	+.04	-.06
59	Hutton and Imray	335	M. T. S	O. S	13.23	75.4	+0.75	+.00180	+1.16	+.72	+1.62	+1.36	+.80	+1.10	+1.17	+1.67	+1.80	+1.36	+1.36
60	Bond	579	M. T. S	O. S	13.92	71.2	+1.41	+.00222	+1.90	+1.34	+1.92	+2.06	+1.48	+2.48	+1.57	+1.51	+1.49	+1.27	+1.30
61	Negus	2087	M. T. S	O. S	14.05	72.9	-0.50	+.00282	+.42	-.40	+.38	+.42	-.60	+.24	-.56	-.67	-.94	-.80	-.73
62	Bond	221	M. T. S	O. S	14.13	94.7	+1.57	-.00125	+1.64	+.74	-.50	-.32	+1.16	+1.44	0.00	+.16	+.34	+.29	+.29
63	Harris	[illegible]	M. T. S		14.13	73.6	+1.45	+.00285	+3.26	+1.46	+2.50	+2.36	+1.44	+1.18	+1.79	+1.49	+1.73	+1.76	+1.53
64	Bliss	2653	M. T. S		14.24	-19.0	-4.17	-.00051	+1.70	-.04	-1.40	-1.38	+.20	+2.02	-.69	-.70	-.63	-.57	-.64
65	Bliss	2995	M. T. S	O. P	14.29	62.3	-4.06	+.00101	-3.14	-4.08	-3.90	-4.10	-3.82	-3.42	-3.96	-3.61	-4.33	-4.21	-4.17
66	Bond	586	M. T. S	O. S	14.96	66.5	+0.50	+.00248	+1.76	+.70	+.94	+.72	+.48	+1.98	+.44	+.40	+.44	+.29	+.21
67	Creighton and Black	2259	M. T. S	O. S	15.15	73.5	+1.56	+.00297	+2.26	+1.58	+2.60	+2.54	+1.54	+2.48	+1.94	+2.04	+2.24	+2.17	+2.24
68	Negus	2032	M. T. S	O. P	15.25	72.2	+1.47	+.00276	+2.12	+1.52	+2.30	+2.28	+1.42	+2.56	+2.13	+1.96	+2.11	+1.86	+1.80
69	Dent	47671	M. T. S	Aux. S	15.57	64.9	-2.15	+.00251	-.48	-1.92	-1.86	-1.94	-2.08	-.64	-2.26	-2.43	-2.57	-2.43	-2.31
70	Negus	1801	M. T. S	O. S	15.77	65.0	-1.16	+.00248	+.38	-1.00	-.84	-.98	-1.04	+.40	-1.07	-1.14	-1.14	-1.36	-1.43
71	Negus	2242	M. T. S	O. P	15.84	211.0	+1.75	-.00013	-.54	-.74	-1.50	-1.32	-.74	+.24	-1.50	-1.34	-1.17	-1.14	-1.04
72	Dent	2474	M. T. S		16.34	72.9	+2.53	+.00272	+3.10	+2.70	+3.42	+3.38	+2.36	+3.56	+2.61	+2.69	+2.83	+2.83	+2.96
73	Fosler-Munroe	259	M. T. S		16.43	94.9	+1.67	-.00165	+1.56	+.80	-.90	-1.02	+.88	+1.70	+.34	-.07	-.09	+.06	+.10
74	Negus	1784	M. T. S	O. S	16.57	54.0	+0.80	+.00176	+2.98	+1.40	+.80	+.80	+1.40	+3.18	+1.04	+.84	+.74	+ 66	+.53
75	Negus	1890	Sid. B. C	O. S	16.71	69.0	-2.29	+.00297	-1.06	-2.22	-1.78	-1.62	-2.28	-.90	-2.04	-2.18	-2.19	-2.28	-2.36
76	Johannsen	6241	M. T. S		16.78	64.6	-0.55	+.00163	+.30	-.10	-.36	-.44	-.80	+.70	+.17	+.24	-.04	+.03	+.26
77	Negus	1291	M. T. S		17.46	70.4	+0.90	+.00315	+2.10	+.86	+1.62	+1.66	+.96	+2.12	+1.21	+1.40	+1.31	+1.20	+1.01
78	Bliss and Creighton	1307	M. T. S		17.63	68.6	+0.27	+.00302	+1.64	+.30	+.84	+.82	+.34	+1.68	+.63	+.49	+.41	+.27	+.29
79	Negus	1260	M. T. S		17.75	66.5	-0.16	+.00277	+1.34	-.28	+.16	+.26	+.16	+1.40	-.01	-.07	-.04	-.09	-.20
80	Bliss	2979	M. T. S	O. P	18.17	71.5	-1.70	+.00276	-.50	-1.50	-.96	-.94	-1.90	-1.02	-1.59	-1.74	-1.80	-1.86	-1.94
81	Sewill	4823	M. T. S	O. S	18.26	54.6	+0.38	+.00198	+2.98	+1.14	+.44	+.32	+.88	+2.72	+.33	+.10	+.11	+.16	-.09
82	Riggs	5087	M. T. S	O. S	18.50	91.1	-0.29	+.00093	-.32	-.10	+.96	+.88	+.16	-.26	-.14	+.34	+.71	+.64	+.59

Data of trial of old chronometers at the United States Naval Observatory, Washington, D. C.

[The signs are astronomical, +losing; −gaining. Data of chronometers with trial numbers greater than 35 omitted]

Order of merit	Chronometer	Kind	Balance hair spring	Trial number	Point of compensation			Mean daily rates										
								Special temperatures						Ordinary temperatures				
	Temperature ... degrees F							90	72.5	55	55	72.5	90	64	61.9	62.4	63.6	63.8
	Balance: O=ordinary; V=invar; Aux=auxiliary Hairspring: S=steel; P=palladium				Temperature	Rate	Temperature constant	Jan. 5–10	Jan. 12–17	Jan. 20–25	Jan. 25–30	Feb. 2–7	Feb. 9–14	Feb. 16–23	Feb. 23–Mar. 1	Mar. 1–8	Mar. 8–15	Mar. 15–22
1	Bliss 3142	M. T. S.	O. P.	1.08	77.5	−1.92	+0.00023	−1.90	−1.96	−1.82	−1.78	−1.86	−1.86	−2.16	−2.21	−2.21	−2.24	−2.36
2	Jensen 76	M. T. S.	V. S.	1.76	62.3	+1.13	−.00020	+.96	+1.00	+1.08	+1.16	+1.22	+1.00	+.97	+.97	+1.09	+1.11	+.97
3	Jensen 75	M. T. S.	V. S.	2.00	75.2	+0.06	+.00033	+.10	0.00	+.34	+.04	+.12	+.16	+.03	+.11	+.14	+.01	+.07
4	Johannsen 4676	M. T. S.	O. S.	2.33	76.2	−2.93	−.00011	−2.80	−2.98	−2.94	−3.02	−2.88	−3.10	−3.00	−2.97	−3.03	−3.06	−3.21
5	Bliss 3112	M. T. S.	V. S.	2.41	186.4	−1.26	+.00006	−.66	−.46	−.14	−.22	−.44	−.70	−.10	−.07	−.21	−.20	−.23
6	Bliss 2959	M. T. S.	O. P.	2.66	138.1	−2.82	+.00013	−2.48	−2.24	−1.90	−1.94	−2.28	−2.56	−2.37	−2.31	−2.27	−2.21	−2.33
7	Nardin 1976	M. T. S.	V. S.	2.79	80.8	−0.45	−.00062	−.52	−.58	−.82	−.90	−.40	−.48	−.66	−.70	−.59	−.77	−.73
8	Negus 2180	M. T. S.	O. P.	2.90	50.1	+0.17	−.00015	−.10	0.00	+.26	+.08	+.20	−.02	−.03	0.00	+.01	+.17	+.19
9	Bliss 2971	M. T. S.	O. P.	2.98	104.2	−1.14	+.00021	−1.00	−1.00	−0.56	−0.70	−0.86	−1.20	−1.07	−1.20	−1.11	−1.09	−1.13
10	Nardin 1864	M. T. S.	V. S.	3.47	69.5	−1.61	−.00119	−2.10	−1.68	−1.82	−1.90	−1.56	−2.12	−1.81	−1.73	−1.73	−1.84	−1.86
11	Kurtz 110	M. T. S.	V. S.	3.49	72.8	−1.15	+.00057	−.86	−.98	−.90	−1.04	−1.32	−1.10	−1.27	−1.23	−1.14	−1.34	−1.24
12	Union 55803	M. T. S.	V. S.	3.50	54.5	−0.77	+.00031	−.40	−.58	−.74	−.80	−.76	−.36	−.70	−.81	−.84	−.76	−.53
13	Diedrich 46	M. T. S.	O. S.	3.73	73.5	−3.12	+.00088	−2.86	−3.32	−2.84	−2.80	−2.92	−2.90	−3.14	−3.03	−3.09	−3.03	−2.97
14	Nardin 661	M. T. S.	V. S.	4.76	28.7	−3.18	+.00026	−2.10	−2.80	−3.06	−2.94	−2.56	−2.30	−2.91	−2.81	−2.80	−2.73	−2.81
15	Bliss 3179	M. T. S.	O. P.	4.79	92.7	−0.46	+.00052	−.34	−.28	+.26	+.30	−.22	−.58	−.11	−.06	+.07	+.14	0.00
16	Negus 1987	Sid	O. P.	4.86	51.2	+1.24	+.00029	+1.84	+1.48	+1.26	+1.22	+1.26	+1.52	+.87	+.82	+.58	+.72	+.70
17	Nardin 2072	M. T. S.	V. S.	5.50	±∞	±∞	.00000	+2.04	+1.46	+1.00	+.94	+1.40	+1.74	+1.29	+1.46	+1.43	+1.29	+1.23
18	Nardin 2058	M. T. S.	V. S.	6.21	−96.9	−18.27	+.00002	−1.58	−2.34	−2.90	−2.82	−2.32	−2.00	−3.19	−3.14	−3.14	−3.11	−3.17
19	Nardin 2065	M. T. S.	V. S.	6.30	73.4	−0.56	−.00124	−.86	−.56	−1.00	−.96	−.56	−.94	−1.00	−.91	−.61	−.54	−.81
20	Kurtz 142	M. T. S.	V. S.	6.47	94.1	−0.93	−.00062	−.86	−1.20	−1.84	−1.92	−1.24	−1.02	−1.76	−1.90	−1.66	−1.57	−1.54
21	Bliss 3152	M. T. S.	O. P.	6.68	117.0	−0.90	+.00039	−.42	−.12	+.54	+.68	−.12	−.80	+.16	+.13	+.09	+.14	+.13
22	Casseres 870	M. T. S.		7.31	51.3	−1.01	+.00074	+.02	−.76	−.90	−1.10	−.60	+.16	−.80	−.80	−.71	−.94	−1.03
23	Negus 2093	M. T. S.	O. S.	7.37	60.0	−1.12	+.00060	−.66	−1.00	−1.06	−1.16	−1.06	−.50	−1.37	−.97	−.83	−.97	−.89
24	Bliss 3184	M. T. S.	O. P.	7.41	76.0	+1.37	−.00086	+1.00	+1.38	+1.00	+.98	+1.34	+1.40	+1.07	+0.86	+0.93	+1.16	+1.34
25	Kurtz 112	M. T. S.	V. S.	7.68	53.2	−0.91	+.00090	+.36	−.68	−.98	−.84	−.48	+.24	−.60	−.49	−.41	−.30	−.37
26	Negus 2197	M. T. S.	O. P.	7.71	56.6	+0.44	−.00052	−.10	+.50	+.44	+.44	+.12	−.18	−.17	−.11	−.01	+.16	+.27
27	Nardin 1621	M. T. S.	V. S.	7.77	156.0	+2.81	−.00024	+1.94	+1.14	+.24	+.38	+1.06	+1.54	+.53	+.50	+.46	+.56	+.59
28	Bliss 2807	M. T. S.	Aux. S.	7.80	69.9	−1.08	−.00163	−1.56	−1.06	−1.38	−1.50	−1.12	−1.92	−1.73	−1.83	−1.86	−1.93	−2.03
29	Negus 1094	M. T. S.	O. S.	7.81	71.2	+1.09	+.00214	+1.82	+1.16	+1.70	+1.60	+1.02	+1.86	+1.43	+1.43	+1.39	+1.31	+1.27

30	Tobias	1371	M. T. S		7.87	101.0	−1.02	+.00064	−1.02	−.46	+.34	+.32	−.54	−.86	−.30	−.13	−.37	−.36	−.56
31	Nardin	2067	M. T. S	V. S	8.06	55.1	−1.95	+.00080	−.80	−1.88	−2.04	−1.84	−1.52	−1.14	−2.10	−2.03	−2.03	−2.01	−2.00
32	Hand	[illegible]	M. T. S	Aux. S	8.07	4.4	−4.51	+.00038	−1.72	−2.66	−3.50	−3.60	−2.88	−1.80	−3.57	−3.53	−3.54	−3.43	−3.66
33	Nardin	881	M. T. S	V. S	8.16	−159.3	−8.03	+.00013	+.14	−1.04	−2.08	−1.98	−.98	+.04	−1.69	−1.71	−1.71	−1.64	−1.59
34	Bliss	3085	M. T. S	O. P	8.23	69.5	+0.03	+.00204	+.94	−.02	+.36	+.56	+.12	+.84	+.01	−.09	0.00	−0.03	−.01
35	Nardin	713	Sid	V. S	8.30	66.1	−1.11	+.00049	−.76	−1.32	−1.28	−.82	−.86	−.90	−.93	−1.21	−1.19	−1.05	−1.23
36	Bond	232	M. T. S	O. S	8.45	71.5	+0.30	+.00193	+.92	+.34	+.84	+.80	+.26	+1.00	+.23	+.21	0.00	−.10	−.11
37	Negus	1155	M. T. S	O. S	8.45	65.4	−0.79	+.00174	+.16	−.74	−.60	−.60	−.66	+.38	−.61	−.71	−.77	−.78	−.77
38	Bond	1029	M. T. S	O. S	9.36	71.2	−1.41	+.00218	−.66	−1.46	−.76	−.92	−1.36	−.62	−1.23	−1.27	−1.29	−1.43	−1.54
39	Bond	531	M. T. S	O. S	9.42	69.2	+0.56	+.00220	+1.42	+.60	+1.06	+.94	+.56	+1.60	+.71	+.69	+.70	+.61	+.57
40	Seckel	483	M. T. S	O	9.52	84.5	−3.08	+.00088	−2.74	−3.00	−2.38	−2.24	−2.90	−3.36	−2.81	−2.76	−2.83	−2.64	−2.69
41	Nardin	2073	M. T. S	V. S	9.73	102.2	+1.99	−.00008	+1.90	+1.90	+1.86	+1.76	+1.94	+2.06	+1.64	+1.64	+2.06	+2.24	+2.19
42	Ehrlich	767	M. T. S	O. S	9.82	77.8	−1.11	+.00201	−.96	−1.14	−.02	−.10	−.96	−.66	−.46	−.44	−.41	−.43	−.43
43	Bond	371	M. T. S	O. S	10.12	77.1	−1.48	+.00206	−1.12	−1.38	−.38	−.58	−1.50	−1.16	−1.00	−.94	−.99	−1.21	−1.14
44	Negus	1519	Sid. B. C	O. S	10.14	66.6	−0.72	+.00212	+.38	−.64	−.46	−.42	−.66	+.50	−.47	−.48	−.52	−.57	−.67
45	Bond	570	M. T. S	O. S	10.36	61.2	−1.28	+.00166	−.06	−1.14	−1.18	−1.26	−1.00	+.26	−1.07	−1.00	−1.07	−1.09	−.97
46	Dent	2523	M. T. S	O. S	10.38	70.2	−0.62	+.00225	+.36	−.56	−.08	−.12	−.66	+.16	−.47	−.67	−.81	−.69	−.61
47	Bond	308	M. T. S	O. S	11.20	62.2	−0.84	+.00165	+.40	−.78	−.88	−.62	−.54	+.48	−.33	−.50	−.60	−.57	−.66
48	Negus	1449	M. T. B. C	O. S	11.46	70.9	+0.09	+.00261	+1.10	+.18	+.74	+.76	+.02	+1.00	+.23	+.31	+.20	+.13	+.11
49	Bliss	3018	M. T. S	O. S	11.58	72.2	−0.05	+.00279	+.86	−.10	+.76	+.80	0.00	+.80	+.07	−.11	+.04	−.04	+.06
50	Dent	49456	M. T. S		11.58	112.5	+1.04	−.00023	+.80	+.34	+.14	+.42	+1.00	+1.04	+56	+.27	+.34	+.23	+.20
51	Kurtz	131	M. T. S	V. S	12.03	52.3	−0.81	−.00080	−1.70	−1.00	−.70	−.94	−1.28	−2.20	−1.66	−1.79	−1.96	−1.99	−2.01
52	Bond	512	M. T. S	O. S	12.10	73.5	+0.48	+.00276	+1.18	+.40	+1.44	+1.40	+.56	+1.28	+.83	+.71	+.64	+.64	+.71
53	Negus	1953	M. T. S	O. S	12.24	68.3	+0.58	+.00258	+1.78	+.60	+1.04	+1.04	+.66	+1.82	+.89	+.80	+.86	+.76	+.74
54	Bond	601	M. T. S	O. S	12.38	76.8	+1.07	+.00227	+1.38	+1.24	+2.20	+2.10	+.98	+1.54	+2.07	+2.26	+2.14	+1.91	+2.07
55	Negus	1265	M. T. S	O. S	12.68	67.2	+2.28	+.00238	+3.46	+2.32	+2.52	+2.76	+2.38	+3.58	+2.36	+2.31	+2.23	+2.17	+2.14
56	Nardin	2066	M. T. S	V. S	12.75	41.7	−1.66	+.00111	+.88	−.70	−1.34	−1.60	−.52	+.98	−1.07	−1.21	−1.29	−1.29	−1.34
57	Negus	1812	M. T. S	O. S	12.82	71.4	+0.55	+.00269	+1.40	+.56	+1.38	+1.16	+.54	+1.56	+.77	+.80	+.79	+.61	+.56
58	Bliss	2872	M. T. S	O. S	13.17	62.8	+0.09	−.00222	+1.64	+.28	+.24	+.22	+.32	+1.82	+.16	+.07	0.00	+.04	−.06
59	Hutton and Imray	335	M. T. S	O. S	13.23	75.4	+0.75	+.00180	+1.16	+.72	+1.62	+1.36	+.80	+1.10	+1.17	+1.67	+1.80	+1.36	+1.36
60	Bond	579	M. T. S	O. S	13.92	71.2	+1.41	+.00222	+1.90	+1.34	+1.92	+2.06	+1.48	+2.48	+1.57	+1.51	+1.49	+1.27	+1.30
61	Negus	2087	M. T. S	O. S	14.05	72.9	−0.50	+.00282	+.42	−.40	+.38	+.42	−.60	+.24	−.56	−.67	−.94	−.80	−.73
62	Bond	221	M. T. S	O. S	14.13	94.7	+1.57	−.00125	+1.64	+.74	−.50	−.32	+1.16	+1.44	0.00	+.16	+.34	+.29	+.29
63	Harris	[illegible]	M. T. S		14.13	73.6	+1.45	+.00285	+3.26	+1.46	+2.50	+2.36	+1.44	+1.18	+1.79	+1.49	+1.73	+1.76	+1.53
64	Bliss	2653	M. T. S		14.24	−19.0	−4.17	−.00051	+1.70	−.04	−1.40	−1.38	+.20	+2.02	−.69	−.70	−.63	−.57	−.64
65	Bliss	2995	M. T. S	O. P	14.29	62.3	−4.06	+.00101	−3.14	−4.08	−3.90	−4.10	−3.82	−3.42	−3.96	−3.61	−4.33	−4.21	−4.17
66	Bond	586	M. T. S	O. S	14.96	66.5	+0.50	+.00248	+1.76	+.70	+.94	+.72	+.48	+1.98	+.44	+.40	+.44	+.29	+.21
67	Creighton and Black	2259	M. T. S	O. S	15.15	73.5	+1.56	+.00297	+2.26	+1.58	+2.60	+2.54	+1.54	+2.48	+1.94	+2.04	+2.24	+2.17	+2.24
68	Negus	2032	M. T. S	O. P	15.25	72.2	+1.47	+.00276	+2.12	+1.52	+2.30	+2.28	+1.42	+2.56	+2.13	+1.96	+2.11	+1.86	+1.80
69	Dent	47671	M. T. S	Aux. S	15.57	64.9	−2.15	+.00251	−.48	−1.92	−1.86	−1.94	−2.08	−.64	−2.26	−2.43	−2.57	−2.43	−2.31
70	Negus	1801	M. T. S	O. S	15.77	65.0	−1.16	+.00248	+.38	−1.00	−.84	−.98	−1.04	+.40	−1.07	−1.14	−1.14	−1.36	−1.43
71	Negus	2242	M. T. S	O. P	15.84	211.0	+1.75	−.00013	−.54	−.74	−1.50	−1.32	−.74	+.24	−1.50	−1.34	−1.17	−1.14	−1.04
72	Dent	2474	M. T. S		16.34	72.9	+2.53	+.00272	+3.10	+2.70	+3.42	+3.38	+2.36	+3.56	+2.61	+2.69	+2.83	+2.83	+2.96
73	Fosler-Munroe	259	M. T. S		16.43	94.9	+1.67	−.00165	+1.56	+.80	−.90	−1.02	+.88	+1.70	+.34	−.07	−.09	+.06	+.10
74	Negus	1784	M. T. S	O. S	16.57	54.0	+0.80	+.00176	+2.98	+1.40	+.80	+.80	+1.40	+3.18	+1.04	+.84	+.74	+ 66	+.53
75	Negus	1890	Sid. B. C	O. S	16.71	69.0	−2.29	+.00297	−1.06	−2.22	−1.78	−1.62	−2.28	−.90	−2.04	−2.18	−2.19	−2.28	−2.36
76	Johannsen	6241	M. T. S		16.78	64.6	−0.55	+.00163	+.30	−.10	−.36	−.44	−.80	+.70	+.17	+.24	−.04	+.03	+.26
77	Negus	1291	M. T. S		17.46	70.4	+0.90	+.00315	+2.10	+.86	+1.62	+1.66	+.96	+2.12	+1.21	+1.40	+1.31	+1.20	+1.01
78	Bliss and Creighton	1307	M. T. S		17.63	68.6	+0.27	+.00302	+1.64	+.30	+.84	+.82	+.34	+1.68	+.63	+.49	+.41	+.27	+.29
79	Negus	1260	M. T. S		17.75	66.5	−0.16	+.00277	+1.34	−.28	+.16	+.26	+.16	+1.40	−.01	−.07	−.04	−.09	−.20
80	Bliss	2979	M. T. S	O. P	18.17	71.5	−1.70	+.00276	−.50	−1.50	−.96	−.94	−1.90	−1.02	−1.59	−1.74	−1.80	−1.86	−1.94
81	Sewill	4823	M. T. S	O. S	18.26	54.6	+0.38	+.00198	+2.98	+1.14	+.44	+.32	+.88	+2.72	+.33	+.10	+.11	+.16	−.09
82	Riggs	5087	M. T. S	O. S	18.50	91.1	−0.29	+.00093	−.82	−.10	+.96	+.88	+.16	−.26	−.14	+.34	+.71	+.64	+.59

Data of trial of old chronometers at the United States Naval Observatory, Washington, D. C.—Continued

Order of merit	Temperature .... degrees F							Mean daily rates										
	Balance: O=ordinary; V=invar; Aux=auxiliary Hairspring: S=steel; P=palladium		Balance hair spring	Trial number	Point of compensation			Special temperatures						Ordinary temperatures				
								90	72.5	55	55	72.5	90	64	61.9	62.4	63.6	63.8
	Chronometer	Kind			Temperature	Rate	Temperature constant	Jan. 5–10	Jan. 12–17	Jan. 20–25	Jan. 25–30	Feb. 2–7	Feb. 9–14	Feb. 16–23	Feb. 23–Mar. 1	Mar. 1–8	Mar. 8–15	Mar. 15–22
83	Bond 303	M. T. S	O. S	18.73	68.6	+1.72	+.00302	+3.04	+1.84	+2.38	+2.18	+1.70	+3.18	+2.10	+1.87	+1.94	+1.80	+1.69
84	Johannsen 879	M. T. S		19.24	71.7	+2.44	+.00255	+3.02	+2.38	+3.40	+2.90	+2.50	+3.56	+2.59	+2.24	+2.33	+2.26	+2.13
85	Johannsen 4743	M. T. S		19.78	228.3	+8.39	−.00039	+.88	−1.42	−3.34	−3.46	−.86	+.88	−2.59	−2.64	−2.63	−2.53	−2.61
86	Dent 49340	M. T. S		19.99	−331.1		+.00015	+.76	−1.46	−3.24	−3.38	−1.16	+.80	−2.20	−2.61	−2.70	−2.63	−2.61
87	Ehrlich 965	M. T. S	O. S	20.72	390.4	−24.04	+.00024	−1.96	+.66	+3.46	+3.58	+.78	−1.90	+2.21	+2.37	+2.41	+2.26	+2.39
88	Moore 2003	M. T. S	Aux. S	20.91	40.9	−3.33	+.00186	+1.20	−1.54	−3.00	−2.92	−1.40	+1.12	−2.36	−2.53	−2.63	−2.57	−2.46
89	Shepherd 486	M. T. S		21.71	75.1	−0.26	+.00330	+.40	−.38	+1.00	+1.14	−.10	+.54	+.16	+.21	−.01	−.16	−.19
90	Negus 2019	M. T. S	O. P	22.11	64.2	−0.97	+.00236	+.64	−.76	−.76	−.78	−.86	+.56	−1.04	−1.80	−1.10	−1.19	−1.19
91	Negus 1451	M. T. S	O. S	22.16	69.9	+0.56	+.00250	+1.74	+.92	+1.32	+.92	+.24	+1.40	+.97	+1.23	+1.33	+.97	+1.00
92	Bond 457	M. T. S	O. S	22.88	77.9	−0.80	+.00245	−.70	−1.06	+.56	+.40	−.40	−.18	−.09	−.09	−.14	−.37	−.39
93	Bond 625	M. T. S	O. S	22.89	82.5	−3.99	+.00250	−3.54	−3.68	−2.04	−2.16	−3.80	−4.16	−3.41	−3.37	−3.56	−3.77	−3.69
94	Fletcher 2121	M. T. S		23.19	75.2	−0.29	+.00351	+.30	−.16	+1.12	+1.18	−.36	+.66	+.14	+.14	+.10	−.10	−.14
95	Negus 2045	M. T. B. C	O. S	23.56	67.9	−3.72	+.00312	−2.02	−3.52	−3.10	−3.30	−3.78	−2.36	−3.47	−3.54	−3.71	−3.86	−3.93
96	Bliss 3033	M. T. S		26.08	62.7	−0.75	+.00263	+.92	−.80	−.62	−.56	−.20	+1.48	−.56	−.39	−.23	−.50	−.53
97	Kulberg 5494	M. T. S		26.34	67.6	+0.14	+.00309	+1.50	+.18	+.68	+.58	+.24	+1.86	+.46	+.04	−.09	−.14	−.27
98	Sewill 4030	M. T. S	O. S	29.08	70.5	−0.06	+.00365	+1.16	0.00	+.78	+.84	−.10	+1.50	+.67	+.37	+.89	+1.06	+.94
99	Bond 199	M. T. S	O. S	30.64	47.1	−0.98	+.00250	+3.62	+.74	−.80	−.84	+.52	+3.60	−.09	−.63	−.64	−.57	−.64
100	Bond 547	M. T. S	O. S	31.97	86.7	−1.29	+.00302	−1.04	−.58	+1.80	+1.70	−.78	−1.48	+.29	+.49	+.31	+.01	−.10

M. T. S.=Mean time standard. M. T. B. C.=Mean time break circuit. Sid. B. C.=Siderial break circuit.

ANNUAL REPORT OF THE
NAVAL OBSERVATORY
FOR THE
FISCAL YEAR 1929

APPENDIX NO. 2 TO ANNUAL REPORT OF THE
CHIEF OF THE BUREAU OF NAVIGATION, 1929

UNITED STATES
GOVERNMENT PRINTING OFFICE
WASHINGTON : 1929

Persons or institutions on a regular mailing list of the Naval Observatory should give prompt notice to the "Librarian, United States Naval Observatory, Washington, D. C.," of any change of address, stating specifically the form of address in which the publication has previously been received, as well as the new address. Notice should be given also when a publication is no longer desired.

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APPENDIX NO. 2

Report of Superintendent of Naval Observatory

NAVY DEPARTMENT,
UNITED STATES NAVAL OBSERVATORY,
Washington, D. C., July 1, 1929.

From: Superintendent Naval Observatory.
To: Chief of Bureau of Navigation.
Subject: Report of the Superintendent Naval Observatory for the fiscal year ending June 30, 1929.

There is submitted herewith the report on the Naval Observatory for the fiscal year ending June 30, 1929, being the eighty-fifth year of the active operation of this institution and the ninety-ninth since the inception of the depot of charts and instruments, which was the forerunner and progenitor of the observatory.

INTRODUCTION

Outlook.—The increasing calls for the observatory's scientific output referred to in the annual report of last year have served to spur on the efforts of the staff to meet such manifest wants. Adjustments of organization and certain personnel additions have enabled the institution to register a reasonable degree of progress during the past fiscal year, but it has become obvious that there is an insistent demand for public service along astronomical and navigational lines which can not be met unless additional funds are made available to provide for such expansion of facilities and modernization of plant as will place the observatory in step with other scientific establishments of similar or analogous aims. With the exception of an instrument originally loaned in 1915 by the International Geodetic Association, the observatory has not been supplied with a single major piece of astronomical apparatus for more than 30 years. The three clocks supplying the country with standard time were purchased over 20 years ago. It is needless to point out the significant improvements in precision clock design that have marked the last quarter of a century and that are incorporated in modern precision timekeepers.

Astronomy.—The heavy routine work inseparable from the prosecution of continuous observing programs on the major instruments has been consistently carried on. It appears important to emphasize the increasing importance of this work now that such work becomes almost exclusively a function of national observatories. It is upon the foundation of data laid up by continuous observations in positional or astrometric astronomy that star catalogues are produced and the accuracy of future ephemerides are assured. The various university observatories and privately endowed observatories, with few exceptions, are devoting themselves to valuable astrophysical work or to short, specialized series of observations along astrometric lines. It follows that the concentration of national observatories on the astronomy of position and the international coordination of their work takes on a vastly augmented importance in the current epoch.

In preparing and publishing the American Ephemeris and Nautical Almanac and in deriving and disseminating the correct time, the observatory has continued to discharge its national function of providing navigators, aeronauts, astronomers, engineers, geodesists, geophysicists, hydrographers, meteorologists, surveyors, and others with fundamental data required by them in pursuing various investigations within their respective provinces, and has likewise served the general public and every agency and individual requiring the provision of accurate time.

An aeronautical supplement to the Nautical Almanac containing moon tables for the use of aviators has been prepared and is in course of publication. Its main purpose is to facilitate aerial navigation by providing a ready means of establishing position rapidly through the employment of the moon and sun in joint observations. The tables, however, are of general application also and will be of assistance to the surface navigator who may choose to employ them.

Navigation.—As was pointed out in the annual report of last year, the demands for exactness of navigation increase markedly with the increase of commercial traffic in the ordinary sea lanes, with the advance of aerial navigation, and with the development of new ideas in gunnery and tactical fields.

An intensive study and analysis of the needs of the naval service in respect to instrumental aids to navigation has led to the establishment of a post-graduate course of study in compass installation and nautical instrument design. The officers selected for the course will study for the first year at the post-graduate school in Annapolis and during the second year in or in the vicinity of New York where much of the manufacture of mechanical and optical nautical instruments is concentrated.

Time.—One of the most significant features of development in the work of the observatory is the added demands made upon the institution in respect to the furnishing of accurate time. During the past fiscal year a third regular time signal, sent out at 3 a. m. seventy-fifth meridian (eastern standard) time, has been added to the broadcast schedule of the Arlington and Annapolis naval radio stations. This signal, which has been repeatedly called for in the past for short periods, provides an excellent comparison signal for the Pacific coast of North America, for the Hawaiian Islands, and for the Pacific Ocean area generally, and has been the subject of favorable remark by users outside of the United States.

On account of the rapidly increasing use of radio and the growing importance of precise determination of frequency, the need for a superaccurate time service becomes more and more pronounced. A standardized time interval is the basis of a standard of frequency, and, because the unformity in the rate of rotation of the earth is more reliable than any precision time device yet designed, it forms the basis of comparison for all precision time measures employed in determining radio frequency standards. However, while the standard time interval, based on the time it takes the earth to rotate through 360° (24 hours) on its axis can be very exactly determined by astronomical observations mathematically reduced to usable form, it still continues to be essential to have a timing equipment to bridge the interval between observations and to provide a means of deducing a working frequency standard. For this purpose, the Naval Research Laboratory and various other laboratories are conducting experiments in timing with the use of a quartz crystal oscillator that may point the way to certain desirable changes in the observatory's timing equipment.

FUNCTIONS AND ASTRONOMICAL REQUIREMENTS

The established purpose or mission of the Naval Observatory is as follows:

> To make such astronomical observations, derive and publish such data, and arrange for the supply of such nautical instruments as will afford to United States naval vessels and aircraft, as well as to all availing themselves thereof, means for safe navigation, including the provision of accurate time and, while pursuing this primary function, to contribute material, within the capabilities of the available astronomical equipment, to the general advancement of navigation and astronomy.

The function of supplying astronomical data and instrumental equipment adequate to the navigational needs of the Navy is a basic and essential duty of the Government which it discharges through the agency of the observatory. It is the observatory's primary and paramount function. In its discharge is comprehended the provision for the Nation's merchant marine of the annual nautical almanac which is necessary to deep-sea navigation. The function of contributing material to the general advancement of navigation and astronomy falls in that category of governmental duties which is comprehended under promotion of the general welfare of the people. Promotion of the Nation's welfare has given rise to the establishment of many of the scientific bureaus of the Government, and has been the origin or source of the major part of the activities of all of them.

The astronomical requirements which are laid upon the observatory by its mission and hence are obligatory on its scientific staff are set forth below under the headings Field of Work and The General Plan.

FIELD OF WORK

The astronomy of position, contemplating continuous observations of the sun, moon, planets, and fundamental stars for the determination of absolute positions, including the position of the equator and equinox among the stars, and essential contributory observations. Other astronomical investigations of general or special scientific value, either independently or in cooperation with other observatories, undertaken so far as time, opportunity, and the demands of the principal observational work of the observatory admit.

Preparation and publication of the American Ephemeris and Nautical Almanac, referred to hereafter as the American Ephemeris.

Derivation and dissemination of correct time.

THE GENERAL PLAN

To maintain a continuous series of observations of the sun, moon, planets, and the standard stars of the American Ephemeris in order to contribute a reserve of data for use in preparing the tables of the American Ephemeris, and in order to provide for the determination of such quantities, including the constant of refraction and the variation of latitude, as are essential to the reduction of such observations.

To maintain a series of observations of such stars as may be selected to serve the possible or probable future needs of the American Ephemeris, being guided

in such selection by the recommendations of the International Astronomical Union or other widely recognized source of authoritative opinion.

To maintain a regular series of observations of occultations of stars by the moon in order to aid in improving the elements of the moon's orbit.

To maintain a systematic series of observations of the satellites of the planets in order to improve the tables of the satellites in the American Ephemeris, to aid in determining the masses and forms of the planets, and to provide data for the investigation of problems connected with satellite motion.

To maintain a series of observations of asteroids for purposes of record and to employ asteroid observations for parallax and other determinations as may be required in improving the tables of the American Ephemeris.

To conduct observations essential to investigation of the astronometric constants used and published in the American Ephemeris, including the constant of aberration and the obliquity of the ecliptic.

To observe comets sufficiently to establish their probable orbits in order to provide data for their further investigation should such investigation prove desirable.

To observe solar eclipses visible at the observatory and total solar eclipses, when practicable, wherever visible, in order to preserve eclipse data for future astronomical investigations.

To secure sun-spot data, in order to insure the supply of such data to the Weather Bureau and other activities for meteorological and electrical investigations.

To engage, after thorough consideration and deliberation, in such astronomical projects or investigations, exemplified in the past by the work of the Transit of Venus Commission and the observations for world-longitude determination, as may come within the purview of the mission of the observatory and be comprehended in its field of work.

To employ photographic methods in carrying on the observational work of the observatory in all cases where astrographic methods may be found to be applicable and to make such methods primary in securing results whenever the results so attained assure the astrometric accuracy required for computing data employed or which may be employed in formulating the tables of the American Ephemeris.

To give habitual and thoughtful consideration to the latest scientific developments and demands in those activities employing the American Ephemeris and Nautical Almanac, in order to be continuously guided as to the contents of the annual volume.

To insure systematic improvement of the tables of the American Ephemeris by continuous theoretical investigations, by discussions of observations, and by the timely use of the latest approved astronomical results applicable to the revision of such tables.

To provide for a wide broadcasting by radio and telegraph and other approved means of the correct time derived by observations with the highest grade transit instruments available; a study and application of all feasible improvements to the time service; and a comparison, where practicable, of the time results of this observatory with those of other time service agencies, with a view to checking the relative accuracy of the results and acquiring data as to future world-longitude determinations and possible improvements in the radio methods employed therein.

ADMINISTRATION OF ASTRONOMICAL WORK

The astronomical council has continued to function as the advisory body which the superintendent employs to keep him authoritatively informed of the progress, needs, character, and outlook of the astronomical work of the observatory. The astronomical work performed in the several divisions of the observation department and in the ephemeris department falls into four general categories: Fundamental positional work, sometimes referred to as meridian astronomy; research work in connection with the positions and motions of the fainter celestial bodies involving considerations of celestial mechanics and sometimes referred to as the astronomy of the equatorials; photographic work, covering all observational fields, but with a technique sufficiently distinctive to merit differentiation into a category of its own; theoretical work, which employs the results of observations in order to formulate the data upon which are predicated the astronomical events and phenomena of the future. The work carried on under these serveral categories is so separate in character as to make essential the training of specialists in each category. And yet it is equally essential that the total astronomical output be so coordinated as to provide for continuity in the general plan of scientific work, without undue emphasis on any of its various important phases.

The astronomical council, composed of the leading astronomers of the observatory, sitting monthly with the superintendent and assistant superintendent, provides the administrative means for insuring that the astronomical activities of the institution shall be carried on in such a manner as to avoid the possibility of one class of work being performed at the expense of another and to permit the leading specialists in the various branches of practical and theoretical astronomy a definite voice in the arrival at administrative decisions affecting their specialties.

OUTSTANDING NEEDS OF THE OBSERVATORY

The last annual report represented the outstanding need of an astrographic laboratory for the Naval Observatory, because of the tendency of the photographic method to supersede eye observations in modern astronomical practice. The need for modern photographic equipment still continues paramount, but other astronomical needs become increasingly pressing as the years pass with nothing added to the observatory's equipment in the way of modern instruments. The world has made enormous strides in the last 30 years in the development of the physical sciences, but the observatory has failed to keep abreast of outside developments. A review of the observatory's past history indicates that at no time has so long an interval elapsed between accessions of improved equipment as has occurred since the ordering of the 6-inch transit circle in 1893 and the present time. No major instrument has been provided for the observatory since 1893, except the incidental acquisition for $1,500 in 1915 of a photographic zenith tube, an instrument originally secured by the international body, known as the International Geodetic Association, for a special series of observations cut short by the World War.

The three standard clocks which measure the national time of the United States and govern the time kept in every industrial establishment and in every community of the country are all more than 20 years old, having been acquired in 1903, 1904, and 1907, respectively. They should be replaced, in view of the signal improvements made in precision clocks in recent years and the increasing demand for superaccurate time in research work of various kinds.

In the apportionment of funds under the budget system the amount of $1,600 is set aside yearly for scientific equipment. Thirty years ago and up until a recent date it was customary to appropriate $2,000 for this purpose. Occasionally $2,500 was appropriated. This meager amount is designed to repair the apparatus now on hand, as well as to make small accessions. If by any chance $2,000 was adequate 30 years ago it is totally inadequate now. Not only can the dollar not buy so much, but the advances in astronomy and in precise instrumentation render obligatory more frequent expenditures than in the past, if modern approved practices are to be followed. Astronomy, in common with most of the physical sciences, develops its own instruments. If an astronomer feels the need of an instrument or an improvement in the instrument he is using he must, in most instances, design the device he wishes and he must have money to produce a finished article. If he habitually fails to obtain what he wishes over a series of years his output suffers. The observatory's output could be improved and the status of its scientific personnel raised if its equipment could be modernized in certain respects and could then be kept up to a first-class standard of efficiency and effectiveness. What equipment is on hand is in generally excellent condition, but it reflects inevitably the quality of its age and date.

The library of the observatory has expanded to such an extent as to present an ever-growing problem in respect to the disposition of new accessions. The weeding out of obsolete or little used material has been carried out with diligence and pains are taken to employ with the utmost effectiveness the space available for the books in hand, but the need for added library facilities continues to be obvious.

The maintenance work of the observatory is handicapped by want of shop and storage facilities and the lack of such concentration of the existing facilities as will permit of ready and effective supervision. The existing conditions in these respects result in loss of time on the part of both skilled and unskilled labor and uneconomical procurement of material. The remedy lies in a grouping of the shop, storage, and transportation facilities in one part of the extensive grounds of the observatory. A specific estimate for a suitable building has been submitted.

Meanwhile the grounds of the observatory are suffering a gradual deterioration which has been remarked upon in several recent annual reports. Every effort is put forth to maintain the property in the parked condition in which it was placed after being taken over by the Government a generation ago. The funds for the purpose, however, have been cut 40 per cent and the purchasing power of the remaining amount for both labor and material has been seriously reduced in the past 15 years.

To summarize it may be said that the scale of upkeep and maintenance in so far as the scientific work of the observatory is concerned should be improved and that a considerably more liberal allowance of funds is necessary, in order to insure the reasonable progressiveness and up-to-dateness that the general public desire of their national institutions. An elaborate provision of funds is not desirable, but a gradual elimination of outstanding defects brought on by age and a too restricted financial outlay is essential to the observatory's lasting national usefulness.

PUBLIC CONTACTS AND GENERAL PROGRESS

Visiting by the general public continues to be a significant feature in the observatory's routine, which requires specific administrative consideration, especially because such visiting occurs mostly at night. More than 3,300 night visitors were received during the past year, including numerous groups from schools at a distance from Washington. In November the visiting delegates to the Michelson meeting of the

Optical Society of America attended an evening exhibit of the observatory's astronomical plant, at which the observatory personnel were hosts. During December the members of the District of Columbia branch of the Optical Society of America were also received by the members of the observatory's scientific staff, and in January the Washington Philosophical Society was similarly received. The delegates of the American Association of Variable Star Observers were extended the same courtesy in May. The visits of members of the Cabinet, Senators and Representatives, and other Government officials continue numerous. The volume of visiting is such as to occupy a significant portion of the time of the astronomers and must be allowed for in planning the accomplishment of the Government's astronomical work. It is because of this liability which visiting lays against the night observing programs that it is necessary to limit to one a week the evenings upon which general visitors are received. It is mandatory also that the number of visitors accorded the night visiting privilege be restricted to approximately 60 per week on account of the space available for handling groups about the instrument employed.

Thirty-three postgraduate students from the postgraduate school of the United States Naval Academy twice visited the observatory for purposes of instruction, once each in the months of July and August. Six officers were given instruction with astronomical and surveying instruments, preliminary to engaging in surveying duty under the Hydrographic Office. Special data for astronomical work on the surveying grounds were prepared and furnished by the observatory. Nine officers of the Navy and three officers of the Coast Guard, all from the Optical School, Washington Navy Yard, made a day's visit of instruction. A naval reserve officer was given one week of compass and navigation instruction.

The detailing of a line officer to the time service and four additional line officers for instruction in the astronomical branch of the observatory has provided a means of familiarizing a body of young officers with the character and quality of the important scientific work the institution is carrying on not only for the Navy, but for numerous other Government departments and the general public as well as for foreign scientific activities with which the observatory may from time to time cooperate. The basic training and experience of these officers along scientific and engineering lines enable them to contribute service of value to the institution while pursuing their several courses of instruction here.

The commanding officer of the Argentine training ship *Presidente Sarmiento*, with 7 officers and 20 cadets, inspected the observatory on October 19, and the party was entertained at an official luncheon given by the superintendent and staff.

Various contributions and lectures on astronomical subjects, tendered by members of the observatory staff, are enumerated elsewhere.

The Third Assembly of the International Astronomical Union, held at Leiden, Holland, in July, 1928, was attended by three members of the astronomical staff in the capacity of delegates. The delegates also attended the meetings of the Astronomische Gesellschaft at Heidelberg and visited various observatories in England and on the Continent. The reports submitted by these delegates on their return, which are based on considered opinions derived from contacts with the leading astronomers of the world, may be summarized as follows:

(*a*) The work being carried on here in the field of meridian astronomy is essential. It should be continued, enlarged upon, and improved. It should be reduced as early, discussed as thoroughly, and published as soon as possible.

(*b*) It is essential that this institution maintain fundamental observations of the sun, moon, planets, and standard stars, and observe the zodiacal and Eros stars.

(*c*) In practically all cases the foreign observatories excel this observatory in the quality and modernity of their instrumental equipment. In upkeep of equipment this observatory ranks especially high.

(*d*) The variation of latitude work and the time service work here are essential and the longitude work is important.

(*e*) Parallax and double star work are being well looked out for.

(*f*) The time is opportune for this observatory to cooperate in carrying out an international plan for systematic observations of all satellites.

(*g*) Astrographic work at this observatory is encouraged. The importance of it conforming to international cooperative plans is stressed.

(*h*) There is strong demand for a new zodiacal catalogue.

(*i*) The revision of Auwers' catalogue and the status of Boss's new catalogue suggest that consideration be given to the formulation of a new fundamental catalogue and to work on the fundamental constants.

The exhibit mentioned in the last annual report as prepared for the International Ibero-American Exposition was received in excellent condition in Seville, Spain, where the exposition is being held. The intent of the exhibit is to emphasize the contribution made by the Navy to the progress of science, and emphasizes particularly the method of handling time dissemination.

Emphasis was laid in the last annual report on the handicap to the observatory resulting from delays in the publication of results obtained from its astronomic work. Certain of the results secured in the normal functioning of the organization it is necessary to make available as early as practicable. The demand for the observatory's output along various lines, especially in connection with time service, is increasing in such a manner as to embarrass the facilities available for publicity and to bring into sharper relief the fact that the observatory has no bulletin service to make ephemeral results of importance immediately accessible to navigators, surveyors, engineers, and others employing them in their professional work. A bulletin or circular issued periodically, as is done by the Hydrographic Office and certain other Government public service activities, would contribute in an especially useful way toward releasing the observatory's astronomical data promptly.

The total solar eclipse of May 9, 1929, was observed at Iloilo, Philippine Islands, under the auspices of the observatory and is treated of elsewhere. The observatory was especially fortunate in securing the cooperation of Prof. William A. Cogshall, of the University of Indiana, an experienced eclipse observer, and of Mrs. Cogshall to augment its eclipse party. Cooperation of outside astronomers in work of this sort, which necessitates absence of some part of the scientific staff from routine work at the observatory, is of the highest importance, in that it directly reduces the number required to be so absent.

A small addition to the photographic house for increasing plate-measuring facilities and star chart manipulation was completed and occupied last October, The instrument maker has been engaged, in addition to his many duties, in constructing a new plate measuring machine of his own designing evolved from ideas furnished him by the head of the astrographic division.

Certain photographic plates of the Potsdam Carte du Ciel zone (+34° and +35°) have been received for consideration, at the request of this observatory, with a view to their possible measurement, if the completion of the international Carte du Ciel project will be aided thereby.

The gyrocompass situation in the Navy continues to show improvement. Successful progress has been made in producing compasses of higher precision than any heretofore turned out in this country. A sea-testing outfit for investigating photographically the action of the gyroscopic installation under open-sea conditions is in a developmental state, a preliminary test having been conducted aboard the U. S. S. *Marblehead* last fall.

Ideas and suggestions looking to the improvement of navigational equipment are habitually being given earnest and thorough consideration. A simple device for taking the place of parallel rulers has recently been designed by an officer on duty at the Naval Academy and will shortly be available for ships. Investigation is being made of the feasibility of reducing the size and weight of the ship's telescope by introducing a prismatic system of optics and successful results appear assured. The dynamic and mechanical features of the magnetic compass and its method of suspension in gimbals is being subjected to an exhaustive analysis. A policy is being followed of challenging the design principles of practically all of the nautical instruments in common use with a view to ascertaining whether they are altogether sound or represent the highest mechanical efficiency in the light of the unprecedented developments in machine technique and engineering and electrical efficiency in the postwar period of the past 10 years.

GRAVITY MEASUREMENTS

On October 2, 1928, the U. S. S. *S–21*, Lieut. J. L. Fisher, United States Navy, commanding, left Washington on a cruise arranged by the Navy Department for the purpose of making gravity measurements at sea. On board for the scientific work of the expedition were Dr. F. A. Vening Meinesz, of the Geodetic Commission of the Netherlands; Dr. F. E. Wright, of the Carnegie Institution, of Washington; and Mr. E. B. Collins, of the Hydrographic Office of the Navy. After leaving Hampton Roads, Va., the *S–21* was accompanied by the United States Eagle boats *Nos. 35* and *58*, forming a division commanded by Lieut. Commander T. L. Nash, United States Navy, who was the officer in charge of the entire expedition. The expedition devoted 56 days to its work, and the *S–21* returned to Washington on November 27, 1928.

The gravity measurements were accomplished by a unique pendulum apparatus designed by Dr. Vening Meinesz and employed previously by him in establishing a world circuit of gravity stations extending from Holland across the Atlantic and Pacific Oceans, by way of the Panama Canal, to the Dutch East Indies, and connecting with Holland again across the northern part of the Indian Ocean and, by way of the Suez Canal, through the Mediterranean Sea. The cruise of the *S–21* covered approximately 7,000 miles along the Atlantic continental shelf and in West Indian and Gulf of Mexico waters, and resulted in the establishment of 49 new gravity stations, 46 of which were open-sea stations, the remainder being in ports visited. A separate report dealing with the scientific aspects of this cruise will be published and distributed shortly.

THE TOTAL SOLAR ECLIPSE OF 1929

An expedition sponsored by this observatory observed the total solar eclipse of May 9, 1929, from a site in Iloilo, Panay, P. I. The site selected was in the grounds of the Philippine Railway Co., adjacent to Lapus Station.

The expedition was in charge of Commander C. H. J. Keppler, United States Navy, and was composed of Prof. William A. Cogshall, of the University of Indiana, the leading scientist of the expedition; of Mrs. Cogshall; of Astronomer Paul Sollenberger, of the naval Observatory staff; and of Lieut. H. C. Kellers, Medical Corps, United States Navy, who, besides looking after the physical welfare of the party, acted also in behalf of the National Museum for the collection of specimens of fauna and flora in the vicinity of the eclipse site. Through the cooperation of Father Selga, director of the Manila Central Observatory, with his extensive knowledge of general and local meteorological conditions throughout the eclipse area in the Philippines, the expedition was signally assisted in its selection of an appropriate location for its observations. Mr. R. R. Hancock, vice president and general manager of the Philippine Railway Co., and his associates in the company extended the expedition many courtesies and contributed much to its success by making available the actual site of the observations on the railway property adjacent to Lapus Station in Iloilo, as well as by affording many facilities in the way of berthing space at the railway wharf, shop equipment, shelter for apparatus and supplies, housing accommodations, and so on. A party of enlisted personnel of the Navy rendered invaluable assistance to the expedition, especially in the construction of the tower and appurtenances for the 65-foot camera, which was the major instrument employed in the observations.

The eclipse itself was favored with almost perfect weather conditions. Fifty-six negatives, with exposures varying from half a second to 65 seconds, were obtained from the six cameras in operation, and in addition, 24 others taken for contact times, 12 each for first and fourth contacts. Two Navy airplanes made observations from the air. Several sketches were made by volunteer observers on the grounds and an artist's impression of the eclipse as it appeared to him in one of the airplanes was secured. Motion pictures were made at Antique at about a thousand feet elevation, and there also a series of exposures with a small camera was obtained, showing the gradual changes in light intensities from first to fourth contacts.

The definitive report of the eclipse observations will be issued as soon as practicable.

PERSONNEL

Capt. A. H. Rice, United States Navy, continued as assistant superintendent and head of the material department until May 20, 1929. During the remainder of the fiscal year the assistant superintendent's duties were divided between the maintenance officer and the compass officer.

Commander S. F. Heim, United States Navy, reported for duty on October 17, 1928, as the relief of Commander I. H. Mayfield, United States Navy, who was detached on October 20, 1929. Commander Heim continued as maintenance officer the rest of the year, and, on January 5, 1929, took over the additional duties of equipage officer, incident to the detachment of Commander W. O. Wallace, United States Navy, on that date. On the same date, Commander C. H. J. Keppler, United States Navy, reported for duty in connection with the Naval Observatory eclipse expedition of 1929, and, after successfully administering the activities of the expedition, was detached on June 27, 1929.

The policy of associating certain younger officers of the Navy with the scientific work of the observatory, in order to secure later the benefit of their trained services, was continued. Among these officers the following changes took place:

Reported for duty.—Lieut. J. A. McNamar, September 4, 1928; Lieut. E. G. Hanson, September 11, 1928; Lieut. T. T. Craven, September 17, 1928; Lieut. J. B. Seletski, September 28, 1928; Lieut. R. P. Glass, March 14, 1929.

Detached.—Lieut. M. E. Eaton, July 31, 1928; Lieut. J. B. Seletski, April 29, 1929.

Among the astronomical staff the following changes are noted:

Commander Asaph Hall, corps of professor of mathematics, who, after his retirement on October 6, 1923, was retained on active duty, was relieved of all active duty at the close of the fiscal year and was detached on June 30, 1929, after having served continuously at the observatory since his appointment as a professor of mathematics in 1908.

Appointments.—To be junior astronomers: Bevan P. Sharpless, January 16, 1929 (temporary appointment, August 16, 1928); Nicholas E. Wagman, January 16, 1929 (temporary appointment, September 24, 1928); Irving A. Kittell, May 16, 1929.

Promotions.—To be senior astronomers: John C. Hammond, James Robertson, Herbert R. Morgan, George H. Peters, July 1, 1928. To be astronomers: Harry E. Burton, Chester B. Watts, Paul Sollenberger, January 1, 1929.

Resignation.—As junior astronomer, Arta H. Hadfield, May 14, 1929.

The quota of scientific aides for computing purposes was maintained at its full strength of 10 for approximately eight months of the year. The experience with these new employees has been in general most gratifying. The lag between the observations obtained and the computations completed has been materially checked. Analysis points to the need of six additional aides, but the accession should be gradual, in order that there may be no tendency to exceed the actual needs of the situation.

The comparative steadiness in the personnel situation in the astronomical branch of the observatory has been reflected in the comparatively heavy output of work. For instance, the number of observations with the 6-inch transit circle more than doubled this year over last. The altazimuth observations numbered almost 2,000 after several years of no observations through press of other work. There has been a considerable gain in the computation work in practically its every phase, although the tendency to lag is still apparent in the new programs, pointing to the fact that the computing staff is not yet at its proper strength.

Earnest efforts are under way to secure a more appropriate grading of certain positions in the observation and ephemeris departments. The extreme technicality of many of the processes essential here in the securing of ultimate astronomical results of value is not always appreciated. The planning, organizing, and prosecution of elaborate programs of work in positional astronomy covering many years in extent call for professional ability of a high order, and the responsibility entailed in accurately reducing the observations, properly discussing them, and employing them with sound judgment as a part of the foundation data that support ultimately the ephemerides of the future call for a unique type of specialized knowledge, which is becoming scarcer and scarcer as young men from the schools turn their attention to the astrophysical rather than to the astrometric features of astronomy. Too much emphasis can not be given to the necessity of grading the positions in the astronomical branch of this institution with such a spread upward as will provide an inviting financial future to the young men and women of the staff in whose hands lies the future of positional astronomy in this country.

On June 30, 1929, the personnel on duty connected with the various activities of the Naval Observatory numbered 117. They were distributed as indicated in the following table:

Personnel on duty at the Naval Observatory on June 30, 1929

	Classification and numbers				
	Naval	Professional	Clerical	Subprofessional and custodial	Total
Astronomical branch	7	31		14	52
Nautical branch	5	2	4	20	31
Administrative	1		5	28	34
Total	13	33	9	62	117
Vacancies	2	1		2	5

Of the personnel attached to the observatory on June 30, 1929, the following have reported for duty during the fiscal year: 6 naval (46 per cent of the 13 listed), 3 professional (10 per cent of the 33 listed), no clerical turnover, 12 subprofessional and custodial (27 per cent of the 62 listed). Of the 117 total personnel, 21 represent the year's accessions, a turnover of practically 18 per cent, with 5 vacancies to be filled at the beginning of the new fiscal year, as contrasted with the turnover of slightly more than 22 per cent in 1928.

MATERIAL DEPARTMENT

The readjustment of organization in respect to the nautical branch of the observatory, noted in the last annual report, has been reflected in increased conservation of funds available for nautical instruments. The variation in the distribution of duties has enabled a closer supervision to be exercised over expenditures for repairs of navigational instruments in the fleet, as a result of which certain improvements have been brought about in the repair facilities of fleet tenders, notably in respect to means for repairing and adjusting gyro compasses afloat.

The function of testing chronometers prior to issue was found to be so closely interlocked with their cleaning, repair, and general upkeep as to warrant shifting the time service section from the equipage division to the maintenance division for ease and effectiveness of administration. The highly important scientific functions of the time service are in no way changed, except as they are benefited by the gain in facility of administration accomplished by the shift.

EQUIPAGE DIVISION

[Commander S. F. Heim, United States Navy, acting head of division]

Equipment section.—The new system of issuing navigational material from stock carried at navy yards and supply depots is now working satisfactorily and results show a saving of time and money over the old centralized system. Certain adjustments may be found necessary in respect to highly technical material, but the principle of decentralization has already given assurance of its soundness.

The study of specifications for navigational material has continued and new specifications have been made or old ones revised, in order to provide the latest and best navigational instruments.

After thorough investigation and consultation with unit commanders afloat, the allowance of standard chronometers was reduced from three to two. This reduction was made possible because of modern radio time service.

The following experimental telescopes were manufactured in the optical shop of the Washington Navy Yard:

2 quartermasters' spyglasses.
2 officer-of-the-deck spyglasses.
1 set of telescopes for high-grade sextants.
1 7 by 50 binocular (fitted with experimental lenses and prisms).

All of the above instruments proved highly satisfactory on test, only minor features of design requiring change.

Six hundred pairs of 6 by 30 binoculars were reconditioned at the Washington Navy Yard.

Reports from ships on tests of the latest bubble sextants were received. None of these tests have shown the sextants to be satisfactory for surface ship navigation. Contract has been made for delivery of five of these sextants of an improved type.

During the year certain navigational equipment was furnished to the U. S. S. *S-21* and the Carnegie Institute of Washington for use in gravity measurement at sea.

Aeronautical section.—Chief Aerographer F. G. Williams, United States Navy, is administering this section of the equipage division, and Lieut. T. C. Lonnquest, United States Navy, of the bureau of aeronautics, is the liaison officer in the cooperative work constantly being carried on between the observatory and that bureau. In the joint work required, the observatory has continued to conduct experiments and engage in research work in regard to the design, development, and improvement of aeronautical material.

The new design Mark IV airplane compass developed by the bureau of aeronautics, after the experimental models were constructed by the observatory, has continued to meet the requirements of the service. During the current year contracts and deliveries to the observatory of sufficient parts for the assembly of 1,200 of this type of compass have been handled. To date about 50 per cent of the above amount have been assembled and distributed throughout the service and to contractors for installation on new airplanes.

Several types of foreign-make airplanes compasses have been delivered, but as yet have not been tested; also several dash-mount compasses. Ten new design aperiodic airplane compasses have also been received, but not tested. Darad bubble octants have been received, tested, and distributed to the service. Three Stetson line of position plotters have been delivered and will be tested. Twenty-three Willson bubble type octants have been received and tested during the year. Twelve bubble chambers for the Willson bubble telescopes, of an approved design, embodying the improvements found to be advisable, and suggested by the observatory, have been delivered and tested.

Continued experiments with various types of drift indicators and course and distance calculators have been made. From the experimental models of post type drift sights constructed by the observatory, the bureau of aeronautics embodied such improvements as found advisable and developed the Mark II drift sight. One hundred of the instruments have been received and distributed, while an additional contract for another hundred has been let.

The observatory has developed and constructed a tripod leveling device upon which bubble octants are tested.

The year has been marked by the active cooperation of the observatory with the bureau of aeronautics in the development of various aerological instruments. Among these were the metallic pilot-balloon plotting board, which after having been discarded was discussed in conference between representatives of the observatory and the bureau of aeronautics. Such alterations and deviations from the original plan as were deemed advisable were incorporated and an experimental model constructed. This model proved satisfactory and a second board constructed which embodied such changes as were found to be advisable. This second board proved to be entirely satisfactory, and plans are now under way for the securing of material for the assembly of a quantity of this type of board.

The observatory has developed for the bureau of aeronautics a current supply unit. Twenty-five of these units were assembled and distributed to the service during the year. Fifteen of the Davis-Radford bubble-type theodolites were received and tested. Various experiments and tests were conducted in order to obtain a suitable design for an air-sounding panel. The observatory at present is constructing an experimental model which, when completed, will be flight tested. A sea-water thermometer developed here has been supplied to the service during the year. The observatory constructed 100 pilot balloon balances of a type and design developed by the bureau of aeronautics during the year.

The observatory maintains constant touch with sources of information abroad, in order to obtain the latest knowledge regarding the development of aeronautical instruments outside of the United States.

COMPASS DIVISION

[Lieut. Commander D. B. Downer, United States Navy, head of division]

The development of more accurate gyrocompasses has been the outstanding feature in the report of progress for the past year. The allowed errors on Scoresby test under the old and the new specifications have been reduced as follows:

	Old	New
Variations in voltage	0.50	0.25
20-hour turntable	.50	.25
48-hour small angle Scoresby	.60	.35
48-hour large angle Scoresby	1.00	1.00
Settling point error	.50	.20

It will be seen that the errors have been reduced approximately one half, except in the case of the large angle Scoresby test where no change was demanded. On the large angle test the compass is subjected to a roll of 80° amplitude, a pitch of 20° amplitude, and a yaw generated by the Scoresby. The test is difficult and similar conditions will seldom be encountered at sea. On the small angle test the compass is subjected to a roll of 30° amplitude, a pitch of 10° amplitude, and a yaw of 10°. These conditions are probably more severe than any under which gun action will be deliberately chosen. Consequently the accuracy of the compass now approaches much more nearly the outstanding requirements for efficient gunnery.

During the past year, too, the error of the transmission system has been reduced from an allowed five-tenths of a degree to a negligible quantity.

During the fall of 1928 sea tests were conducted aboard the U. S. S. *Marblehead* of a Sperry Mark X gyrocompass and an Arma Mark IV gyrocompass. The observations were made by motion-picture cameras so mounted as to record at one-second intervals all required data as to time and compass action and readings both during straightaway runs and during turns. The apparatus for conducting the test was in a developmental state and several defects in it will require correction before further tests are conducted. From the incomplete results so far obtained from the data, which is still in the reduction stage, the compasses show surprisingly small errors developing as a result of turns.

A latitude and longitude indicator has been developed which, when connected to the dead reckoning tracer equipment, will give with great accuracy the ship's dead reckoning position. This instrument has been made a part of the dead reckoning tracer equipment and it is hoped to complete the equipment of all battleships, aircraft carriers, first line, and light cruisers, first line, in this respect within the next two years.

The time is at hand when the question of replacing the gyrocompass installations aboard our destroyers must be seriously considered. The destroyer type gyrocompass was a new development at the time of initial purchases and the first compasses delivered are showing signs of deterioration through age, indicated largely by increasing faults in operation. The necessity for latitude corrections and for dampening eliminations has become evident and the new compasses for destroyers must incorporate these features.

Efforts are being made to supply all destroyers and other combatant ships not having self-synchronous alidades with the newly developed telescopic alidade.

Tests are being conducted with magnetic compasses with a view to using a special mineral oil as the liquid filler. A suitable gasket has been developed to withstand oil action, but the card itself will require lightening and its action will require dampening. The investigations incident to this proposed change have developed the need of dynamically balancing the compass card to obviate an error otherwise introduced on intercardinal headings. The question of gimballing is also being considered and studies so far conducted suggest the advisability of shifting the suspension points through 90°.

Statistical data.—Contracts have been let for gyro equipment for the following ships of the Navy: U. S. S. *Chester*, U. S. S. *Louisville*, U. S. S. *Chicago*, U. S. S. *Houston*, U. S. S. *Augusta*, U. S. S. *Arizona*, and U. S. S. *Pennsylvania*. A contract has been let for 10 self-synchronous alidades for the battleships *Arizona* and *Pennsylvania*, and the light cruisers *Northampton*, *Chester*, and *Houston*. A contract has been let for 10 dead-reckoning tracers for the battleships *Arizona*, *Pennsylvania*, *Arkansas*, and *New Mexico*, and the light cruisers, *Omaha*, *Concord*, *Richmond*, *Northampton*, *Chester*, and *Houston*. Contracts have been let for latitude and longitude indicators for the battleships *Arkansas*, *New Mexico*, *Arizona*, *Pennsylvania*, *California*, *West Virginia*, *Tennessee*, *Colorado*, *Florida*, *Wyoming*, and *New York*, and the light cruisers *Pensacola*, *Salt Lake City*, *Omaha*, *Concord*, *Richmond*, *Northampton*, *Chester*, and *Houston*, and the aircraft carriers *Lexington* and *Saratoga*.

New installations of old salvaged Sperry Mark II equipments on the following vessels have been authorized: U. S. S. *Kittery*, U. S. S. *Sapelo*, U. S. S. *Patoka*, U. S. S. *Pecos*, U. S. S. *Galveston*, and U. S. S. *Denver*.

A Sperry Mark VIII compass was installed on the U. S. S. *Reno* and U. S. S. *Farragut* in place of the Sperry Mark VI compass.

The modernization of Sperry Mark II compasses was continued during the year, and 12 compasses have been completed.

MAINTENANCE DIVISION

[Commander S. F. Heim, United States Navy, head of division]

The maintenance division is so named because of its concern with that one of the primary functions of the observatory which has to do with taking the necessary steps for maintaining the supply of nautical instruments required for the Navy. It is a function distinct from the actual acquisition of such material, which is accomplished through the regular supply channels of the service administered by the Bureau of Supplies and Accounts. It has to do not only with insuring that new material is available, but that old material is kept in proper repair. As has been noted previously, the time-service section is placed in this division because the upkeep and repair of chronometers and other precision timepieces, naturally a function of the maintenance division, is closely associated with certain of the auxiliary functions of the time service.

This division, organized in the fiscal year 1928, has now passed through its experimental and tentative stage and is proving a pronounced assistance in the economical employment of the "Instruments and Supplies" appropriation. Marked saving is experienced in the repair of precision timepieces. Success has attended the steps taken to convert a surplus war stock of patrol boat chronometers into second-setting navigational watches. A balanced work load for the repair shop is insured through the establishment of cordial cooperative relations with various Government activities requiring occasional precision repair work. This occasional work is not permitted to interfere with the repair shop's service to the fleet.

Close study has been given to the effect of the change resulting from the provision that the observatory no longer is the source of supply for the navigational instruments of the Navy, the responsibility for the maintaining of adequate stocks of navigational material having been turned over to the Bureau of Supplies and Accounts. As noted in the last annual report, this plan began operating with considerable evidence of success. This success is now confirmed, except in certain particulars which have to do with the supply of a necessary stock of spare parts for optical instruments and timepieces of all sorts. On account of the highly technical nature of this material the widely fluctuating demands for its use which militate against the maintenance of reasonably active stocks of such parts, and the difficulty of insuring that the various navy yards and supply depots shall have stockmen sufficiently informed of the distinctions in, let us say, clock parts that may be differently referred to by different repairmen, it is possible that it will be found more economical and more conducive to the prompt distribution of material to make provisions for maintaining a central supply of such technical parts with a technical stockman in charge. The very extended delays now suffered by vessels of the fleet in securing minor, but important, instrument parts for essential repairs are a source of much concern to the observatory.

Statistical data.—The navigational-instrument repair shop has continued to function with a full load of work on precision instruments. The personnel of the shop has been slightly increased during the year.

Two important shipments of scientific instruments, the Iloilo eclipse expedition and the Seville Exposition display, were packed and shipped by the shipment section and reached their destination in excellent condition.

In addition to the routine work on instruments for stock and for ships, the repair shop has done work as follows for various activities of the Navy Department and for other departments of the Government:

Contingent and miscellaneous expenses, Naval Observatory, 1929	$79.62
Ocean and Lake surveys, Bureau of Navigation, 1929	1,677.92
Current and miscellaneous expenses, Naval Academy, 1929	474.92
Organizing the Naval Reserve, 1929, subhead No. 17	6.67
Pay, miscellaneous, 1929, subhead No. 16 (board of inspection and survey)	6.40
Contingent expenses, Navy department, 1929	52.27
Maintenance, Bureau of Yards and Docks, 1929	67.65
Ordnance and ordnance stores, Bureau of Ordnance, 1929, subhead No. 1	1,224.50
Engineering, Bureau of Engineering, 1929	283.24
Maintenance, Bureau of Supplies and Accounts, 1929, subhead No. 1	5.25
Medical Department, Bureau of Medicine and Surgery, 1929	10.35
Aviation, Navy, 1929	4,399.35
International Exposition at Seville, Spain (State transferred to Navy, act Mar. 3, 1925), 1928	46.80

Department of Commerce Orders Nos. 10940 and 29–7161	$474. 48
Party expenses, Pacific coast, U. S. Coast and Geodetic Survey, 1929	20. 90
Contingent expenses, Coast Guard, 1929	5. 35
Repairs to Coast Guard vessels, Treasury Department	56. 27
Fertilizer investigations, Bureau of Chemistry and Soils, Department of Agriculture	18. 74
Total	8, 910. 68

Summary of work on instruments:

	1929	1928
(*a*) Timepieces of all classes and types	1, 090	972
(*b*) Navigational and surveying instruments	4, 686	1, 806
(*c*) Aviation and aerological instruments	558	918

Value of stock on hand, July 1, 1928	$450, 724. 41
Value of instruments, etc., purchases	73, 553. 42
Value of instruments, etc., from stations and ships	112, 691. 92
	636, 969. 75
Value of instruments, etc., issued and expended	212, 625. 01
Value of stock on hand June 30, 1929	424, 344. 74

	Navigational	Aeronautical	Total	Total last year
Number of shipments received	1, 035	289	1, 324	2, 878
Number of instruments and parts received	12, 593	45, 487	58, 080	61, 107
Number of shipments made	682	679	1, 361	1, 325
Number of instruments and parts shipped	7, 875	23, 271	31, 146	39, 943

Value of instruments purchased and received from stations and ships per fiscal year:

Fiscal year—	
1925	$260, 129. 48
1926	259, 103. 01
1927	258, 071. 33
1928	362, 309. 92
1929	186, 245. 34

Value of instruments issued and expended to stations, ships, etc., per fiscal year:

Fiscal year—	
1925	$193, 467. 86
1926	229, 674. 33
1927	1, 406, 979. 35
1928	843, 120. 37
1929	212, 625. 01

Time service.—Astronomer Paul Sollenberger has continued as supervisor of the time service. He was absent from January 16 through the end of the fiscal year as a member of the Naval Observatory eclipse expedition of 1929. During this period Astronomer C. B. Watts acted in an advisory capacity for the time service.

Time signals were sent out by the Naval Observatory via naval radio stations, as shown in the following table. Arlington and Annapolis are operated directly by the Naval Observatory clock. The other stations receive the signals through the Western Union lines, usually from the Naval Observatory. The noon signals were distributed to nearly all parts of the United States by the Western Union and Postal Telegraph Cos.

[A1 = Unmodulated continuous waves; A2 = continuous waves modulated at audible frequency; K. C. = frequency in kilocycles; W. L. = wave length in meters; K. W. = power in kilowatts; 75 M = seventy-fifth meridian time]

Call	Location	K. C.	W. L.	Kind	K. W.	Signals ending at—		Dates
						G. C. T.	75 M.	
						Hours		
NAA	Arlington, Va.	113	2,653	A2	10	3	10 p. m.	Throughout year.
						8	3 a. m.	June 1 to June 30, 1929.
						17	Noon	Throughout year.
	Do.	690	434.5	A2	1	3	10 p. m.	Do.
						17	Noon	Do.
	Do.	4,015	74.7	A2	10	3	10 p. m.	Do.
						17	Noon	Do.
	Do.	8,030	37.34	A2	10	3	10 p. m.	Do.
						8	3 a. m.	Do.
						17	Noon	Do.
	Do.	12,045	24.9	A2	10	3	10 p. m.	Do.
						17	Noon	Do.
NSS	Annapolis, Md.	17.6	17,040	A1	350	3	10 p. m.	July 1, 1928–Mar. 9, 1929.
						8	3 a. m.	
						17	Noon	
	Do.	17.8	16,840	A1	350	3	10 p. m.	Mar. 10, 1929–June 30, 1929.
						8	3 a. m.	
						17	Noon	
NPL	San Diego, Calif.	30.6	9,798	A1	80	17	Noon	Throughout year.
		102	2,939	A1	2.0	17	do	Do.
NAR	Key West, Fla.	106	2,828	A1	2	17	do	Do.
NAJ	Great Lakes, Ill.	122	2,458	A2	1.0	17	do	Do.
NAT	New Orleans, La.	102	2,883	A1	1.5	17	do	Do.
NPW	Eureka, Calif.	108	2,776	A1	2.0	17	do	Do.
NPE	Astoria, Oreg.	102	2,939	A2	2.0	17	do	Do.

The following naval radio stations send time signals, at hours indicated, but these stations are not under the control of the Naval Observatory:

Call	Location	K. C.	W. L.	Kind	K. W.	Signals ending at—		Dates
						G. C. T.	75 M.	
						Hours		
NBA	Balboa, C. Z.	46	6,518	A1	100	4	11 p. m.	Throughout year.
						18	1 p. m.	Do.
NPO	Cavite, P. I.	56	5,354	A1	30	3	10 p. m.	Do.
						14	9 a. m.	Do.
	Do.	108	2,776	A2	6	3	10 p. m.	Do.
						14	9 a. m.	Do.
	Do.	8,872	33.79	A2	0.25	3	10 p. m.	Do.
						14	9 a. m.	Do.
	Do.	13,308	22.40	A2	10	3	10 p. m.	Do.
						14	9 a. m.	Do.
NAX	Colon, C. Z.	132	2,271	A2	5	4	11 p. m.	Do.
						18	1 p. m.	Do.
NPM	Honolulu, T. H.	26.1	11,490	A1	350	24	7 p. m.	Do.
		106	2,828	A2	2	24	do	Do.
NPG	San Francisco, Calif.	42.8	7,005	A1	100	6	1 a. m.	Do.
						20	3 p. m.	Do.
		66	4,543	A1	40	6	1 a. m.	Do.
						20	3 p. m.	Do.
		108	2,776	A2	0.5	6	1 a. m.	Do.
						20	3 p. m.	Do.

The signals from Annapolis and the 113-kilocycle signal from Arlington were automatically recorded on the chronograph whenever possible; the 4,015-kilocycle signal from Arlington was recorded at 10 p. m. and the 8,030-kilocycle signal at noon and 3 a. m. The time signals from Rugby, England, and Bordeaux, France, were recorded throughout the year.

Due to accidental causes, the signal at 8 hours on January 10, 1929, was sent out with an error of 0.42 second; the signal at 8 hours on June 16, 1929, was sent out with an error of 0.22 second; and the signal at 17 hours on June 21, 1929, was sent out with an error of 0.31 second. Except for these signals the maximum error of any signal was 0.19 second, and the average error was 0.030 second. These errors refer to the times of transmission from the Naval Observatory and not to the times of emission from the radio stations, which were generally larger. The list of errors of the signals, which was formerly mailed at monthly intervals to scientific users of the signals, has been prepared and forwarded at weekly intervals since April 1, 1929, to reduce as far as possible the delay in making the signals available for precise investigations involving time.

The signal at 3 a. m., formerly sent intermittently as a special signal upon request of the United States Coast and Geodetic Survey and the Canadian Geodetic Survey, has been made a part of the regular time service program.

Experimental work has been directed toward improving the radio recording apparatus and other equipment utilized by the time service. Mr. Sollenberger, shortly before his departure on the eclipse expedition, began experiments with methods for driving a precision pendulum, which will be resumed on his return. Prin transit No. 1 has been provided with a new driving mechanism for the impersonal micrometer, which permits of more accurate following of stars under observation. This apparatus, devised by Mr. Watts, consists of a small synchronous motor mounted on the micrometer and geared directly to the screw, the speed of rotation being controlled by the observer by regulating the frequency of the current which drives the motor.

A trial of old chronometers was held during the year, beginning October 19, 1928, and ending January 6, 1929. The data for chronometers making trial numbers less than 35 are given in a table elsewhere in this report.

During the fall of 1928, a board of officers was convened for the purpose of studying the existing time signal system and making recommendations for improvements in it. The board made an exhaustive analysis of Navy time dissemination and arrived at certain important conclusions. Time signals sent out were found to fall in three general classes which, for purposes of differentiation, were referred to as signals of the first, second, and third orders. First order signals are those of the highest precision sent out from precisely regulated transmitting clocks of high initial accuracy by stations connected closely with the source of transmission, so that relay lags are reduced to a minimum. Such are the signals sent out by the Arlington and Annapolis radio stations, which are connected practically direct with the Naval Observatory. Second order signals are those sent out from accurately rated transmitting clocks over long leads of wire, introducing varying degrees of lag. They give results suitable for chronometer rating for navigation and for other purposes where the highest degree of precision is not essential. Such are the signals sent out from Key West, New Orleans, Great Lakes, and San Diego. Third order signals are those sent out from clocks set by comparison with first or second order time signals. These clocks are not always actual transmitting clocks; they are frequently set by hand by observers who have listened in on other time signals, and the time of emission is sometimes several hours after the receipt of the correcting first or second order signal. These signals are subject to errors sometimes running into seconds of time. They are wholly unreliable for scientific purposes, but are sufficiently accurate for the ordinary requirements of commerce and industry. Such are the signals at present sent out from Balboa and Colon in the Panama Canal area.

The several recommendations of the board are still under review by the various agencies affected and improvement in time broadcasting will be the outcome of their application. It is to be noted that the problems of the time service are principally problems in more accurate dissemination of time rather than in its correct derivation and initial transmission. The Navy is fully alive to the high desirability of an effective solution of such problems.

EPHEMERIS DEPARTMENT

The needs of the ephemeris department continue, in large measure, to govern the output of the observation department. It appears pertinent to emphasize the direct and mandatory connection between these two major departments of the astronomical branch of the observatory, especially because of the utilitarian nature of the work turned out by the ephermeris department. In addition to the Nautical Almanac, which is a maritime or navigator's handbook used not only by the vessels of the Navy, but by the shipping of the American merchant marine as well, the ephemeris department also publishes annually the American Ephemeris, which is employed by various Government departments, as well as by astronomers, engineers, meteorologists, physicists, surveyors, and others as an essential compendium of data necessary for the carrying on of their work. In addition, the ephemeris department is continuously engaged in research and investigatory work in theoretical astronomy. The results of such work, including star catalogue work as well, are included in a series of volumes appearing from time to time under the caption "Astronomical Papers of the American Ephemeris." The daily duties of the ephemeris department are of course distinct from those of the observation department, its computations being based on the published transactions of all well-attested observatories, as well as upon data exchanged directly with certain foreign almanac offices in accordance with law.

The department has continued under the direction of Capt. W. S. Eichelberger, corps of professors of mathematics, United States Navy.

Beginning with the volume of the American Ephemeris for 1931, the sun's longitude will be referred to the mean equinox of the beginning of the year instead of the true equinox of date; the sun's latitude will be given referred to the ecliptic of the beginning of the year and referred to the ecliptic of date; the sun's rectangular coordinates will be referred to the mean equator and equinox of the beginning of the year; the values of the Besselian star numbers will be given as well as their logarithms; in the computation of eclipses, the longitude of the sun from Newcomb's Tables will be increased 1″.5; and in the computation of the Elements for the Prediction of Occultations, the mean longitude of the moon from Brown's Tables will be increased

$7\overset{\prime\prime}{.}0$, as has been done in the computation of eclipses for a number of years. The eclipse maps have been reduced to the size of one page, a white and stippled black impression being used instead of the former color effect.

Work has been continued on the new zodiacal catalogue.

In the last annual report it was stated that a list of stars was being selected to be included in the new zodiacal catalogue, which list should contain all the stars in the Harvard Photometry of magnitude 7.0 or brighter that were not included in Hedrick's Catalogue or in Gill's list. Three hundred and forty-five such stars were found. Modern positions of these stars will be furnished by the Cape Observatory and by the Naval Observatory. The information concerning these stars contained in Index der Sternorter 1900–1925, by R. Schorr and W. Kruse, has been entered on cards for use in determining their positions.

To the 10 catalogues listed in the last annual report from which is to be formed a normal position for each of the zodiacal stars, approximately at the epoch 1905, there has been added the Radcliffe Catalogue of Stars, 1900; and to the five catalogues from which similar positions are to be formed for the approximate epoch 1915 has been added the San Luis Catalogue, 1910.

Work on the investigation of the orbits of Saturn's satellites has been confined to the comparison of Barnard's observations 1917–1922, with theory.

In addition to the head of department, the following were employed on the work of this department during the year: Senior Astronomer James Robertson; Associate Astronomers Arthur Snow, Walter M. Hamilton, George F. Crawley; Assistant Astronomers Perez Fisher, Morris Liferock, Isabel M. Lewis; Junior Astronomers Charles L. Rush, Rudolph J. Joers, Charlotte Krampe, and Glen H. Draper; and the following piecework computers: Janet McWilliam, Hannah F. M. Hedrick, Thomas E. Trott.

OBSERVATION DEPARTMENT

The general plan of work (p. 3) governs the investigations and observations undertaken with the major instruments of the observatory under specific programs designed to use to the fullest advantage the known capabilities of the instruments. It is the aim of the observatory so to arrange and coordinate the work programs as to preserve a definite continuity in the series of observations of the sun, moon, planets, and the fundamental stars selected to form the observing lists.

Coordination is assured through the administrative agency of a duly constituted committee composed of the heads of the divisions of the observation department. All observing programs thus receive expert technical analysis and consideration before being finally reviewed by the astronomical council, which passes upon their adoption. The exhaustive examination to which observing programs are subjected before they are adopted does not act to restrict the initiative of the responsible heads of division. It does, however, serve to iron out idiosyncrasies in methods that might serve to handicap progress; it provides for a suitable interlocking of programs having certain aims in common, and acts to prevent undesirable duplication of results.

NINE-INCH TRANSIT CIRCLE DIVISION

[Senior Astronomer Herbert R. Morgan, head of division]

NINE-INCH TRANSIT CIRCLE

Program.—Observations of—

I. Sun, moon, and planets.
II. Selected standard stars (2,440).
III. Selected intermediary stars (7,561).

Purpose.—

I. To secure data for improving the elements of the orbits of the moon and planets; for the determination of the celestial equator, of the equinox, and of the obliquity of the ecliptic.
II. To secure data for improving the positions and proper motions of the standard stars for use in national ephemerides.
III. To secure data for referring to the standard stars the reference stars used in reducing the plates of the photographic chart of the heavens (Carte du Ciel).

Continuity.—The current program, begun in 1913, is now in the reduction and discussion stage, all observations having been completed in 1926.

Work on the reductions of 72,330 observations made with this instrument from 1913 to 1926 has been continued throughout the year. The apparent places are completely reduced, and the mean places are reduced to 1923. These reductions have been substantially furthered by an increase in the computing personnel, over 9,000 reductions to mean place having been made in duplicate this year. The observations are collected on the cards to November, 1922, and the positions of mean epoch are being determined.

Corrections for clamp differences have been determined and applied to all declinations. An investigation has shown that the personal equation in declination has been largely eliminated by use of the reversing prism. The relative personal equations in right ascension for stars of all declinations, and for the sun, moon, and planets have been derived from the observations and then combined with the absolute equations from the personal equation machine, and the necessary corrections applied for the whole work. There are no corrections for stars south of the zenith, and they are small for stars north. The differences between day and night observations of clock stars have been determined, and day corrections in right ascension and declination have been applied to observations of the sun, Mercury, and Venus.

The moon observations taken here from 1894 to 1922 have been collected, reduced to a uniform system, including the more important differences between Brown's and Hansen's tables, and certain discussions made. The individual residuals, now available in manuscript, are to be published in an observatory volume.

The personnel of this division, in addition to its head, consisted of Associate Astronomer Jesse Pawling and Assistant Astronomer U. S. Lyons, both of whom have certain observing duties in other divisions. Three subprofessional aides have been computing on this work under assignment in this division and a variable number under assignment in the computing section.

SIX-INCH TRANSIT CIRCLE DIVISION

[Senior Astronomer J. C. Hammond, head of division]

SIX-INCH TRANSIT CIRCLE

Program.—Observations of—

I. Sun, moon, and planets.
II. Selected zodiacal stars (about 3,500).
III. Selected standard stars (about 2,500).
IV. Selected stars for refraction (about 40).
V. Ceres and Vesta.
VI. Eros at opposition of 1930–31.

Purpose.—

I. To secure data for improving the elements of the moon and planets; for the determination of the celestial equator, of the equinox, and of the obliquity of the ecliptic.
II. To secure data for the preparation of a new catalogue of zodiacal stars.
III. To secure data for improving the positions and proper motions of the standard stars for use in national ephemerides.
IV. To secure data for the determination of the constant of refraction.
V. To secure additional data for determining the position of the equator and the equinox among the stars.
VI. To secure data for the determination of the solar parallax.

Continuity.—The current program, begun in 1928, is planned for approximately six years, and contemplates inclusion of previous observations since 1925 under the first subhead, in the discussion of results. No work under the third and sixth subheads is contemplated until 1930.

Observations of the sun, moon, planets, and zodiacal stars were continued through the year. The observations of the zodiacal stars were half completed on May 11, and the work was resumed on May 17, after an interchange of micrometer and objective and a rotation of the circle on its axis by 43° 28′. The minor planets Ceres and Vesta were observed for periods of four and five months, respectively.

The number of observations made during the year is as follows:

Sun	169	Ceres	22
Moon	115	Vesta	28
Mercury	63	Clock stars	3, 040
Venus	107	Azimuth stars	380
Mars	21	Refraction stars	351
Jupiter	16	Zodiacal stars	7, 565
Saturn	14		
Uranus	15	Total	11, 921
Neptune	15		

The observations are reduced through apparent place to March 15, 1929, and the mean place reductions to 1925 for the zodiacal stars are completed to August 1, 1928. The results of the observations of the Eros stars in 1927 and 1928 were published in Astronomical Journal 915 and the observations of the moon in 1928 in Astronomical Journal 923.

A new switchboard designed by Mr. Watts, controlling the circuits from the standard clocks to the various instruments, was installed in July, 1928.

The microscope heads of the instrument were regraduated in April so that the sum of the readings gives the seconds of the circle reading without the division by four. A considerable saving of time has been effected by their use.

The stellar focus was adjusted twice, once on October 25 and again on April 4.

The instrument was reversed 25 times, and the number of determinations of its instrumental constants is:

Collimation	432	Azimuth from marks	884
Level	996	Nadir	1,043

The personnel of this division, in addition to its head, consisted of Astronomer C. B. Watts, Associate Astronomer J. E. Willis, Assistant Astronomer G. C. Whittaker, Junior Astronomer A. H. Hadfield until May 15, and Junior Astronomer B. P. Sharpless from June 1.

CLOCK VAULT

The temperature in the clock vault was maintained practically constant at 84° F. during the year. Riefler No. 70 was used as the standard clock and ran very satisfactorily. Riefler No. 151 was cleaned and oiled in July. It was assembled without the minute and hour hands and without certain parts of the train used in driving these hands. This is an experiment to determine whether a decrease in friction in the train will result in improving the rate of the clock. Certain mechanical troubles developed which caused this clock to run irregularly during the remainder of the year. Riefler No. 60 was unsealed in November and again in December to remedy a mechanical trouble in the winding mechanism. A leakage of air developed in the clock case of No. 60 in March which was finally located and remedied on May 6.

The following table gives the mean daily rates of the three Riefler clocks in the vault, and the maximum variations in the rates for each month:

	No. 60		No. 70		No. 151	
	Mean daily rate	Maximum variation	Mean daily rate	Maximum variation	Mean daily rate	Maximum variation
1928	*Second*	*Second*	*Second*	*Second*	*Second*	*Second*
July	0.00	0.02	0.00	0.02		
August	−.01	.01	−.01	.02		
September	−.01	.01	−.01	.02		
October	−.01	.02	.00	.02	+0.12	0.05
November			+.02	.03	+.08	.05
December			+.03	.01	+.02	.13
1929						
January	+.12	.01	+.04	.01		
February	+.12	.01	+.05	.02	−.15	.12
March			+.04	.04	−.26	.13
April			+.02	.02	−.32	.04
May			+.02	.02	−.10	.09
June	−.16	.01	.00	.02	−.18	.08

Total variation in daily rate during the year: No. 70, $0^{s}.08$.

ALTAZIMUTH AND ZENITH TUBE DIVISION

[Capt. F. B. Littell (Math.), United States Navy, head of division]

ALTAZIMUTH

Program.—Observations of declinations of sun, Mercury, Venus, Ceres, Vesta, and selected standard stars.

Purpose.—To secure data for improving declinations of objects observed; for the determination of the constant of refraction; for the determination of the celestial equator, of the equinox, and of the obliquity of the ecliptic.

Continuity.—The current program, begun in 1928, is planned for approximately five years and contemplates inclusion of previous observations in the discussion of results.

The plan of work for the altazimuth outlined above comprises declination observations of the sun, Mercury, Venus, Ceres, and Vesta, and of the stars of the list in Volume X, Part I, Astronomical Papers of the American Ephemeris and Nautical Almanac, being observed simultaneously with the 6-inch transit circle. Observations during the year were as follows:

Sun	139
Mercury	36
Venus	68
Ceres	11
Vesta	23
Stars	1, 685
Total	1, 962

The sun observations from May to December, 1928, have been preliminarily reduced, and indicate that the altazimuth instrument is well adapted for these observations.

PHOTOGRAPHIC REFLEX ZENITH TUBE

Program.—Observations of zenith distances of eight groups of eight stars each, two groups being observed at any given season.

Purpose.—To determine the variation of latitude at the Naval Observatory, the aberration constant, and eventually the nutation constant.

Continuity.—The current program, begun in 1915, is planned to proceed continuously.

Observations with the zenith tube have been continued as usual. Approximately 1,863 stars on 278 plates were secured. The results of the observations for the year 1927.0–1928.0 have been published in the Astronomical Journal.

The personnel of the division, in addition to its head, has been as follows: Associate Astronomer G. M. Raynsford, to May 31; Assistant Astronomer W. M. Browne; Associate Astronomer J. Pawling (observing only); Junior Astronomer J. D. Phenix (observing only until June 1, when assigned to division for full time). One subprofessional aide has been engaged in computing under assignment in this division, in addition to a variable number under assignment in the computing section. Three naval officers under instruction have also participated in observations with the zenith tube.

EQUATORIAL DIVISION

[Commander Asaph Hall (Math.), United States Navy, head of division]

TWENTY-SIX-INCH EQUATORIAL

Program.—Observations of—

I. Positions of satellites.
II. Occultations of stars by the moon.
III. Positions of asteroids and comets.
IV. Eclipses of satellites of Jupiter.

Purpose.—To secure data for the determination and improvement of the elements of the orbits of the observed bodies; the determination of the masses and forms of the planets; the investigation of other problems connected with satellite and asteroid motions; also to supply data for checking the rotation time of the earth.

Continuity.—The current program, begun in 1908, except for the observations of satellite eclipses, which were begun in 1921, is planned to proceed continuously. There has been little change in the observing program for this instrument since its original installation in 1873.

Observations have been made as follows:

Occultations	33	Satellites of Mars	19
Eclipses of Jupiter's satellites	5	Satellite VI, Jupiter	3
Double stars	32	Satellites of Saturn	20
Comet 1929a (Schwassmann-Wachmann)	1	Satellites of Uranus	13
		Satellite of Neptune	14

The double stars that were measured belong to the system 70 Ophiuchi. They were observed at the request of Dr. A. D. Risteen, of Hartford, Conn., who is making an investigation of this system.

From the observations of the satellites of Mars secured in 1926, corrections have been found to the elements of the orbits of those bodies.

Also, a discussion has been made of the motions of the elements of the orbits of the satellites of Mars, making use of all available material. This includes the Washington observations of 1877, 1879, 1892, 1894, 1896, 1907, 1909, 1924, 1926.

Some time was spent in computing from assumed elements places of Rhea and Titan, satellites of Saturn, for comparison with observations.

In October the Repsold micrometer was removed from the instrument and cleaned. During the cleaning interval a Hartmann test of the objective of the 26-inch equatorial was made by Mr. Wagman of the astrographic division, following the method given by Hartmann in Publikationen des Astro-Physikalischen Observatoriums zu Potsdam, vol. 15. The resulting "technical constant" of the glass was found to be 0.62, which is "good" in Hartmann's classification. Comparison of this value with those found for other glasses, however, shows it to be only average. The greatest difference in focal lengths of the various zones of the glass was slightly more than two-tenths of 1 inch.

A more rigid test of the objective is planned using the visual rays, for which it is corrected, by employing iso-chromatic photographic plates with a "minus-blue" color filter.

In October, also, the observatory mechanics raised the 26-inch dome on jacks and removed the vibration from the side wheels.

TWELVE-INCH EQUATORIAL

Program.—Observations of—

I. Occultations of stars by the moon.
II. Positions of asteroids and bright comets.
III. Eclipses of satellites of Jupiter.

Instrument is also especially used for practice observations and for permitting visitors to view the heavens.

Purpose.—To secure data for correcting the tables of the moon and improving the elements of the moon's orbit; to provide records for determining and improving the orbits of asteroids and comets; also to supply data for checking the rotation time of the earth.

Continuity.—The current program, begun in 1908, except for the observations of satellite eclipses, which were begun in 1921, is planned to proceed continuously, with such modifications as changing methods of securing astronomical data may warrant. The instrument is being employed as an auxiliary rather than a principal instrument of the observatory, and its employment, except in connection with visitors, is intermittent and in lieu of or in addition to the 26-inch equatorial and either under conditions where a smaller equatorial yields the better results or where check observations, as in the case of occultations, are desirable.

With this instrument were observed 28 occultations and 6 eclipses of Jupiter's satellites. Also, observations of asteroids were secured as follows:

Ceres (1)	4	Astraea (5)	2
Pallas (2)	2	Hebe (6)	2
Juno (3)	3	Europa (52)	1
Vesta (4)	7		

The observatory was open to visitors by card or letter for viewing the heavens through this instrument on 85 nights, of which 11 were cloudy. There were 2,602 visitors, including those received on special nights assigned to schools.

The personnel of the division, in addition to its head, consisted of Astronomer H. E. Burton (astronomer from January 1); Junior Astronomer J. D. Phenix, until June 1; and Associate Astronomer G. M. Raynsford, from June 1. Mr. Phenix had certain observing duties in another division.

ASTROGRAPHIC DIVISION

[Senior Astronomer George H. Peters, head of division]

TEN-INCH PHOTOGRAPHIC TELESCOPE

Program.—Observations of—

I. Positions of asteroids.
II. Eros at opposition of 1930–31.
III. Major planets and moon.

Purpose.—

I. To secure data for determining and improving the orbits of asteroids.
II. To secure data for the determination of the solar parallax.
III. To experiment in determining positions differentially.

Continuity.—The current program in respect to asteroids was begun in 1912, similar work having been done with a 6-inch lens since 1903. The remainder of the program was instituted in 1928, and is pursued as opportunity offers, no work being contemplated under the second subhead until 1930. The entire program is planned to proceed continuously.

After a general overhauling, this instrument is now in operation. Many improvements have been made, mostly by the instrument maker and electrician of the observatory at comparatively small expense.

The pair of 10-inch triple photographic lenses of 113 inches focal length were recollimated by a rotational method and remounted on the telescope.

The instrument has been rewired. A transformer for a 6-volt current on the illumination circuit was provided, the 110-volt current being used only on the electric driving clock line, and for the wall lights of the observing room.

New fixtures for illuminating both fine and coarse divisions on the hour and declination circles were installed with convenient control switches. Contact rings were provided on the polar and declination axes, eliminating hanging wires. The fine hour circle was numbered on the 10 minute divisions and its reading microscopes furnished with negative eyepieces giving larger fields.

A pair of miscroscopes for reading the fine declination circle have been installed to replace those transferred to the 26-inch equatorial mounting when constructed by Warner and Swasey. The objectives and large total reflecting prisms for these microscopes were obtained from the optical shop of the Washington Navy Yard. A spare low-power eyepiece was transferred from the 12-inch equatorial for one of these microscopes, while M. E. Kahler, its maker, furnished a duplicate for the other. Some of the original fixtures of the old mounting were available in the new assemblage. The erecting and some machining was done by the nautical instrument repair shop under direction of Mr. Jacob Rheinbold.

A geared slow motion in declination operated by a handle near the eye-end of the instrument was constructed by the instrument maker, dispensing with a belt and pulley arrangement that formerly gave much trouble.

It is proposed to have an adjustable rheostat control near the micrometer of the guiding telescope to vary the rate of the driving clock for refined corrections in guiding. This will dispense with the use of the slow-motion ropes, except for setting adjustments, in right ascension.

In addition to asteroid observations now being made, a list of 17 southern stars on the 6-inch transit circle program, too faint for that instrument, will be observed differentially with this telescope. A few of these negatives have already been secured. The balance will be made when the positions of the regions involved are most favorable.

PHOTOHELIOGRAPH

Program.—Photographs of sun daily.

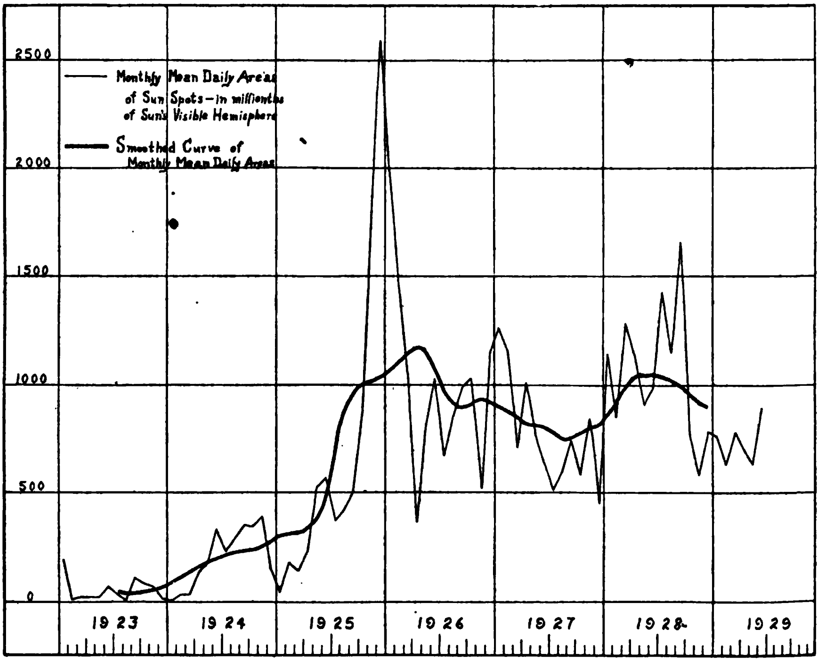
Purpose.—To secure sun-spot data, in order to insure the supply of such data to the Weather Bureau and other activities for meteorological and magnetic or electrical investigations.

Continuity.—The current program, begun in 1897, is planned to proceed continuously.

Observations of the sun were made with the photoheliograph on 297 days. Solar spots or groups were found on all these plates except for November 25, 1928.

Sun-spot activity, considering June 30, 1929, as a limiting date, has definitely declined, although a secondary maximum may occur later.

The curve of activity, from the last minimum in 1923 to date, has been derived, and is reproduced graphically in this report. A strong peak occurred in April, 1926, succeeded by a gradual decline until October, 1927. The culminating maximum before the final decline in intensity took place in September, 1928. Using areas in millionths of the sun's visible hemisphere for the ordinates and monthly averages as abcissæ, this graph indicates a double maximum with peaks of less than the average intensity but extending over a longer time interval.



Wolf's sun-spot relative numbers show a peak of 70.8 about December 15, 1926, followed by a slight decline with a maximum of 76 about the middle of April, 1928.

Publication of current solar observations has been continued in the Monthly Weather Review. Dates missing at the Naval Observatory on account of weather conditions have been supplied generally through the cooperation of the astronomical laboratory, Harvard College, or the Yerkes, or Mount Wilson Observatories. In this manner data for all but four days of the past year have been secured.

Advance information regarding sun spots has been furnished the Western Union Telegraph Co. as usual. While the sun-spot maximum has passed, that of terrestrial magnetic disturbance is expected probably in the ensuing year. The characteristics of the class of spots supposed most effective in producing these conditions are being studied in connection with reports of disturbances and interference to traffic on the lines of the Western Union Telegraph Co.

Junior Astronomer N. E. Wagman has been associated with the work of this division since September 24, 1928.

COMPUTING SECTION

[Associate Astronomer Eleanor A. Lamson, supervisor of section]

This activity of the observatory occupies a place of peculiar importance in the astronomical organization. Its output measures the speed and promptness with which the results of the observing astronomers can normally be expected to be made available for general use. A well manned and efficiently operating computing unit is essential in any observatory organized to perform a public service function.

The computing section has been engaged throughout the year in reducing the observations made in the observation department. The number of personnel in this activity has been materially increased over that of years prior to 1928, the year in which the gradual accession of subprofessional aides began. The normal strength of the section is 12 computers, but this strength was maintained through only approximately eight months of the past year, due largely to difficulty in obtaining satisfactory appointees during the early months of the year. The work of the observatory can be more satisfactorily handled if a further increase of computers is allowed, but the increase should be gradual now that the disastrous lag of a year ago has been somewhat checked and the observatory has been enabled to take up a new and well-considered program of meridian work.

In addition to the routine work of this section, the supervisor has been occupied with the computations incident to the gravity determinations made during October and November by Dr. F. A. Vening Meinesz aboard the U. S. S. *S-21* while cruising in West Indian and Gulf of Mexico waters, and has assisted in the preparation of the definitive report of the expedition.

There follows an outline of the general character of the routine work of the section for the past year, it being noted that certain of the computers have been assigned directly to the various observing divisions for the performance of their computations.

For the 9-inch transit circle division.—Work has been done on the mean place reduction of stars observed from February, 1920, to March, 1923.

For the 6-inch transit circle division.—Work has been done on the reduction of the right ascensions and declinations of the current observations, July, 1928, to July, 1929.

For the equatorial division.—Work has been done on the current observations. Early in the fiscal year Volume XII, Publications of the United States Naval Observatory, second series, was sent to press. This volume consists of two parts and an appendix. Part I contains the observations made with the 26-inch and 12-inch equatorials, 1908–1926, with discussions. In Part II are printed the observations made with the photographic equatorial, 1912–1924, and the observations made with the photoheliograph, 1917–1927. In the Appendix are the results derived from the World Longitude operation of 1926 as made at San Diego and Washington. Of this material the galley proof and 140 pages of the first page proof have been read.

For the astrographic division.—The current sun-spot data have been prepared for publication monthly and sent to the Weather Bureau for insertion in the Monthly Weather Review.

The prime vertical observations, 1921–1925.—Of the list of approximately 820 stars, observed during the years 1921–1925, the apparent declinations have been obtained to March 26, 1925. The mean place reductions and the computations of the precessions and secular variations for the epoch 1925.0 are being made.

LIBRARY

	Volumes	Pamphlets	Total
Contents of the library July 1, 1928	34,346	7,061	41,407
Accessions	307	2,838	3,145
Contents of the library June 30, 1929	34,653	9,899	44,552

Of the publications of this institution, 5,204 copies were distributed, including 364 copies of the American Ephemeris for the year 1929 and 1,473 copies of the American Nautical Almanac for the year 1929.

Books charged to borrowers at the end of the fiscal year numbered 2,293, including volumes loaned to other Government libraries on interlibrary loan.

Although the library has been handicapped by the want of a regular librarian, the assistant has accomplished a great deal of much needed work. All current accessions have been catalogued and some progress has been made on back cataloguing. The catalogue of the library is being shifted over to permit the use of Library of Congress cards. Subject entries have been made for all current cataloguing and a beginning has been made on the older items.

The collection is peculiarly rich in old works on astronomy and mathematics, containing some original editions of the fifteenth century and many of the sixteenth and seventeenth. The library is therefore a source of reference for historians, as well as astronomers and mathematicians, and a certain measure of the work of the library is devoted to answering reference questions and preparing occasional exhibits of ancient volumes.

As mentioned elsewhere, the essential need of the library is additional space. Habitual attention is being given to the timely retirement of volumes and pamphlets that are deemed to have served their purpose. Where practicable, such works are disposed of to other Government libraries or agencies that may designate a desire for them. Otherwise it is the current practice to list such works, box them, and place them in storage in the naval reservation at Bellevue. This policy, designed to maintain the circulation of the library contents at a high point of vitality, does not, of course, insure the necessary space for the annual accessions. Provision for additional shelving continues mandatory.

PUBLICATIONS OF THE OBSERVATORY

Volume XII, Naval Observatory Publications, second series (591 pages), was in page proof as the fiscal year closed. It will be published at an early date and will contain the equatorial observations for the period 1908–1926, the photographic equatorial observations for the period 1912–1924, the photoheliograph observations for the period 1917–1927, and an appendix setting forth the results of the observations made at San Diego and Washington during the world longitude operation of 1926.

The American Ephemeris for 1931 was received from the printer on July 3, 1929.

The American Nautical Almanac for 1931 is in type and should be received from the printer during the summer of 1929.

The Lunar Ephemeris for Aviators, September 1–December 31, 1929, is in type and will be ready for distribution shortly. The issue of this new publication for the period January 1–April 30, 1930, is practically ready for the printer and should be distributed during the autumn of 1929.

More than two-thirds of the copy of the American Ephemeris for 1932 has been sent to the printer, and 195 pages are in type.

CONTRIBUTIONS ON ASTRONOMICAL SUBJECTS

In the Astronomical Journal:

1. Observations of Comet Pons-Winnecke (1927c), by H. E. Burton (No. 885).
2. Variation of Latitude Observations, by F. B. Littell (No. 914).
3. Observations of Eros Comparison Stars, by J. C. Hammond, C. B. Watts, and J. E. Willis (No. 915).
4. Observations of 70 Ophiuchi, by H. E. Burton (No. 918).
5. Occultations of the Moon, 1928, by A. Hall, H. E. Burton, and J. D. Phenix (No. 919).
6. Observations of the Moon in 1928 at the United States Naval Observatory, by J. C. Hammond (No. 923).
7. On Facilitating the Accurate Solution of Kepler's Equation by the Use of Exact Equivalents, by J. E. Willis (No. 923).
8. Elements and Ephemeris of 1906 VE, by E. C. Bower, of Wesleyan University Observatory, and J. E. Willis.
9. Observations of 1908a, by E. C. Bower, of Wesleyan University, and J. E. Willis.

Miscellaneous: A series of monthly articles on astronomical subjects, by Isabel M. Lewis, published in Nature Magazine. (A similar series was erroneously ascribed to "Nature" instead of "Nature Magazine" in the last annual report.)

Lectures and papers:

Before American Astronomical Society, Amherst, Mass., September, 1928, by H. R. Morgan and G. M. Raynsford:

1. Results of Reflection Observations.

Before Maryland Academy of Sciences, Baltimore, Md., November, 1928, by G. H. Peters:

2. The Sidereal Heavens.

Before Maryland Academy of Sciences, Baltimore, Md., April, 1929, by G. H. Peters:

3. The Solar System, Part I, The Sun and Solar Eclipses.

Before the Civitan Club, Washington, D. C., May, 1929, by G. H. Peters:

4. The United States Naval Observatory.

Before American Physical Society, Washington, D. C., April, 1929, by G. H. Draper:

5. A Theory of Light.

Before American Geophysical Union, Section on Goedesy, Washington, D. C., April, 1929, by C. B. Watts.

6. Recent Developments in Time Service Methods.

Before American Geophysical Union, Washington, D. C., April, 1929, by C. S. Freeman.

7. The Gravity Measurement Cruise of the U. S. S. S-*21*.

Before Young Women's Christian Association, Washington, D. C., May and June, 1929, by C. B. Watts.

8. A series of six lectures on general astronomy.

UPKEEP

The gradual deterioration of buildings, grounds, and roads, through lack of funds, continues. Every effort is made with the force and funds available to hold this deterioration in check and to accomplish such slight improvement in conditions as savings in expenditures in other directions permit. The several major jobs of painting required for preservation purposes, mentioned in the last annual report, still remain undone, because no funds could be secured for their accomplishment. The grading and clearing work essential where certain unimproved Government property of the observatory abuts on district and private property which has been improved, also remains undone through failure to secure funds requested for such work.

Emergency repairs to the marble balustrade surrounding the dome of the 12-inch equatorial and to about 100 feet of the heating-pipe tunnel were completed at the beginning of the year with funds secured through a deficiency appropriation.

The observatory's funds for contingent and miscellaneous expenses have been completely consolidated in the appropriation for 1930. The financial administration of the observatory can not help but benefit from this procedure. It is necessary, however, to emphasize most earnestly the essential need of a substantial increase in the funds available for the maintenance of buildings, grounds, and roads. An application to the District of Columbia government to place in presentable condition the considerable area of ground between the Federal property line and the street curbing has met with refusal, the district authorities stating that it is the duty of the abutting property owners to look out for such areas. This decision adds several acres to the already extensive park that must be kept in some reasonable state of upkeep. The gradual deterioration of buildings and roads, and the falling-off in the appearance of the grounds due to the impossibility of attending properly to tree and vegetation growth are a source of concern and embarrassment to successive superintendents, and, as has been previously reported, are beyond administrative control or correction in the absence of funds.

C. S. Freeman,
Captain United States Navy, Superintendent.

Approved, September 3, 1929.

R. H. Leigh,
Rear Admiral, United States Navy, Chief of Bureau.

Data of trial of old chronometers at the United States Naval Observatory, Washington, D. C.

[The signs are astronomical, + losing; − gaining. Data of chronometers with trial numbers greater than 35 omitted]

Order of merit								Mean daily rates										
								Special temperatures						Ordinary temperatures				
	Temperature.......degrees F.							90	72.5	55	55	72.5	90	68.4	67.4	66.1	67.6	65.7
	Balance: O=ordinary; V=invar; Aux.=auxiliary Hairspring: S=Steel; P=Palladium		Balance hair-spring	Trial number	Point of compensation			Oct. 19-24	Oct. 26-31	Nov. 2-7	Nov. 9-14	Nov. 16-21	Nov. 24-29	Dec. 1-8	Dec. 9-16	Dec. 17-24	Dec. 26-31	Jan. 1-6
	Chronometer	Kind			Temperature	Rate	Temperature constant											
1	Negus 1986	M. T. S.	O. P.	.86	81.2	+1.26	+0.00015	+1.30	+1.22	+1.34	+1.38	+1.32	+1.24	+1.41	+1.46	+1.55	+1.53	+1.50
2	Bliss 3141	M. T. S.	O. P.	3.54	155.7	−.63	0.00006	−.76	−1.08	−1.36	−1.22	−1.08	−1.06	−1.61	−1.48	−1.70	−1.63	−1.70
3	Hornby 1392	M. T. S.		3.95	75.8	+1.60	+0.00090	+1.72	+1.70	+2.00	+1.98	+1.52	+1.84	+1.37	+1.33	+1.35	+1.25	+1.07
4	Bliss 3200	M. T. S.	O. P.	4.26	49.8	−.47	0.00049	+0.44	−0.14	−0.42	−0.50	−0.30	+0.20	−0.57	−0.51	−0.48	−0.58	−0.57
5	Bliss 3154	M. T. S.	O. P.	4.75	37.5	−1.39	0.00010	−0.86	−1.24	−1.42	−1.30	−1.30	−1.38	−2.01	−1.97	−2.07	−1.95	−1.94
6	Negus 1980	M. T. S.	O. P.	5.22	73.5	−1.09	0.00020	−0.54	−1.00	−1.62	−1.74	−1.20	−0.74	−1.49	−1.36	−1.43	−1.43	−1.45
7	Nardin 2039	M. T. S.	V. S.	5.67	87.3	−0.15	0.00101	−0.20	−0.32	−1.22	−1.14	−0.40	−0.10	−0.62	−0.68	−0.52	−0.57	−0.62
8	Kurtz 132	M. T. S.	V. S.	5.88	154.1	−0.19	0.00095	+0.26	−0.28	−0.94	−0.86	−0.28	+0.18	−0.90	−0.83	−0.55	−0.66	−0.69
9	Negus 1899	M. T. S.	O. P.	6.45	71.1	+0.58	0.00178	+1.22	+0.66	+1.16	+0.98	+0.56	+1.26	+0.49	+0.43	+0.53	+0.28	+0.37
10	Negus 2250	M. T. S.	O. P.	6.53	72.4	+2.44	0.00100	+3.00	+2.46	+2.76	+2.72	+2.42	+2.50	+2.50	+2.59	+2.73	+2.60	+2.86
11	Benson 7960	M. T. S.		6.54	108.8	+1.72	0.00114	+1.52	+1.76	+2.02	+2.08	+1.98	+2.00	+2.33	+2.31	+2.58	+2.43	+2.61
12	Negus 2182	M. T. S.	O. P.	7.07	82.8	+0.41	0.00038	+0.66	+0.36	+0.68	+0.72	+0.54	+0.20	+0.17	+0.13	−0.12	−0.03	−0.23
13	Riggs 4614	M. T. H.	O. S.	7.92	70.2	+0.65	0.00054	+1.34	+0.72	+1.16	+1.08	+0.60	+1.56	+0.73	+0.80	+0.73	+0.70	+0.80
14	Nardin 1652	M. T. S.	V. S.	8.51	111.4	+0.01	0.00023	+0.18	+0.32	+0.80	+0.68	+0.40	+0.06	+0.49	+0.50	+0.95	+0.87	+0.97
15	Nardin 681	M. T. B. C.	V. S.	8.95	10.6	+1.20	0.00013	+2.82	+2.18	+1.88	+1.84	+2.22	+2.42	+2.01	+2.06	+2.27	+2.48	+2.20
16	Woolf 3195	M. T. S.	O. S.	10.21	37.5	−2.50	0.00100	−0.20	−1.40	−0.60	−0.86	−1.58	−0.24	−1.49	−1.44	−1.47	−1.35	−1.59
17	Kurtz 138	M. T. S.	V. S.	10.30	148.6	+1.22	0.00085	+1.28	+0.52	−0.84	−0.62	+0.46	+1.58	−0.20	−0.04	−0.17	+0.03	−0.09
18	Negus 2122	M. T. S.	O. S.	10.82	60.3	−0.47	0.00125	+0.68	−0.52	−0.74	−0.46	−0.42	+0.18	−1.23	−1.22	−1.32	−1.32	−1.11
19	Negus 2121	M. T. S.	O. S.	11.08	50.1	+0.36	0.00038	+1.34	+0.40	+0.44	+0.30	+0.70	+0.58	+0.01	+0.01	−0.08	+0.03	+0.01
20	Bliss 3093	M. T. S.	O. P.	11.67	−372.2	−9.81	0.00005	+0.34	−0.10	−1.06	−1.10	−0.60	+0.48	−0.61	−0.71	−0.67	−0.92	−1.01
21	Bond 495	M. T. S.	O. S.	11.78	70.0	+0.03	0.00193	+0.98	+0.26	+0.44	+0.48	−0.18	+0.62	−0.34	−0.53	−0.53	−0.66	−0.60
22	Leroy 1171	M. T. S.	V. S.	12.18	149.9	+1.76	0.00020	+1.32	+0.68	+0.28	−0.28	+0.50	+0.82	−0.09	−0.07	−0.02	−0.02	−0.17
23	McGregor P/3628	M. T. S.	O. S.	12.49	60.4	−0.03	0.00137	+1.52	−0.34	−0.04	−0.10	−0.12	+0.94	−0.96	−0.76	−0.70	−0.80	−0.80
24	Crisp 3021	M. T. S.	O. S.	12.61	68.4	−1.27	0.00153	−0.48	−1.08	−0.90	−1.08	−1.40	−0.62	−1.87	−1.83	−2.08	−2.34	−2.33
25	Bond 548	M. T. S.	O. S.	12.80	62.8	−0.65	0.00191	+0.72	−0.58	−0.60	−0.46	−0.36	+0.82	−0.69	−0.39	−0.42	−0.68	−0.44
26	Bliss 3087	M. T. S.	O. P.	13.14	72.3	−0.21	0.00080	−0.10	+0.04	+0.06	0.00	−0.46	+0.16	−0.11	−0.57	−0.69	−0.87	−0.71
27	Negus 599	M. T. S.	O. S.	13.30	65.0	−1.24	0.00166	−0.34	−0.76	−0.98	−1.18	−1.54	−0.08	−1.20	−1.73	−1.32	−1.52	−1.66
28	Bliss 3079	M. T. S.	O. P.	13.75	87.3	+0.31	0.00137	+0.42	+0.30	+1.82	+1.66	+0.92	+0.22	+1.17	+1.08	+1.25	+1.08	+1.14

Data of trial of old chronometers at the United States Naval Observatory, Washington, D. C.—Continued

[The signs are astronomical, + losing; − gaining. Data of chronometers with trial numbers greater than 35 omitted]

Order of merit								Mean daily rates										
								Special temperatures						Ordinary temperatures				
	Temperature						degrees F..	90	72.5	55	55	72.5	90	68.4	67.4	66.1	67.6	65.7
	Balance: O=ordinary; V=invar; Aux.=auxiliary Hairspring: S=Steel; P=Palladium		Balance hair-spring	Trial number	Point of compensation			Oct. 19-24	Oct. 26-31	Nov. 2-7	Nov. 9-14	Nov. 16-21	Nov. 24-29	Dec. 1-8	Dec. 9-16	Dec. 17-24	Dec. 26-31	Jan. 1-6
	Chronometer	Kind			Temperature	Rate	Temperature constant											
29	Bruce 2476	M. T. S.	O. S.	13.98	70.6	−2.00	0.00234	−1.00	−2.18	−1.40	−1.46	−1.80	−1.22	−2.17	−1.87	−2.33	−2.17	−2.07
30	Har Pur 406	M. T. H.		14.12	70.7	−0.21	0.00178	+0.58	−0.12	+0.38	+0.14	−0.22	+0.40	−0.66	−1.40	−1.05	−1.18	−1.23
31	Johannsen 2122	M. T. H.	O. S.	14.47	61.5	−1.81	0.00267	−0.18	−1.38	−1.74	−1.70	−1.72	+0.02	−1.70	−1.86	−1.85	−1.72	−1.73
32	Negus 2087	M. T. S.	O. S.	14.93	69.6	−1.46	0.00283	+0.14	−1.28	−0.78	−0.64	−1.30	−0.40	−1.29	−1.21	−1.25	−1.50	−1.04
33	Walker 459	M. T. S.	O. S.	15.28	60.3	−2.69	0.00222	−0.90	−2.62	−2.76	−2.58	−2.38	−0.84	−2.89	−2.82	−3.02	−2.84	−2.91
34	Bond 594	M. T. B. C.	O. S.	15.46	75.6	−0.75	0.00451	+0.04	−0.70	+1.04	+1.28	−0.72	+0.32	+0.71	+0.65	+0.65	+0.73	+0.79
35	Bliss 2684	M. T. S.	O. P.	16.14	38.4	−0.03	0.00104	+2.66	+1.32	+0.28	+0.24	+1.06	+2.86	+1.18	+0.72	+0.87	+0.86	+0.63
36	Bond 572	M. T. S.	O. S.	16.92	75.1	+0.27	0.00313	+1.02	+0.40	+1.54	+1.54	+0.18	+0.90	+0.29	+0.36	+0.33	+0.15	+0.34
37	Bond 327	M. T. S.	O. S.	17.02	65.0	+0.20	0.00287	+1.90	+0.40	+0.50	+0.48	+0.32	+2.08	+0.19	+0.02	+0.26	+0.10	+0.07
38	Negus 1305	M. T. S.	O. P.	18.23	+63.5	+0.52	0.00215	+1.92	+0.94	+0.76	+0.60	+0.46	+2.16	+0.33	+0.13	+0.42	+0.62	+0.41
39	Negus 1696	M. T. S.	O. S.	18.84	62.8	−0.78	0.00285	+0.94	−0.58	−0.62	−0.62	−0.50	+1.32	−0.83	−1.03	−1.12	−1.05	−1.14
40	Negus 2198	M. T. S.	O. P.	18.86	128.7	−0.60	0.00023	−0.22	+0.04	+0.58	+0.96	+0.24	−0.28	−0.81	−0.42	−0.43	−0.16	+0.16
41	Poole 1513	M. T. H.		19.11	70.3	−1.20	0.00264	−0.44	−0.90	−0.56	−0.60	−1.48	+0.08	−0.93	−0.82	−0.72	−0.83	−0.79
42	Riggs 5661	Sid. B. C.	O. S.	19.63	79.9	−0.02	0.00020	+2.88	+2.94	+2.94	+2.50	+2.74	+2.78	+3.30	+2.77	+2.30	+2.60	+2.40
43	Negus 1989	M. T. S.	O. P.	19.64	73.0	+2.15	0.00287	+2.70	+2.12	+3.20	+2.94	+2.18	+3.28	+2.49	+2.42	+2.80	+2.68	+2.79
44	Negus 2014	M. T. S.	O. S.	20.30	58.3	−2.03	0.00220	+0.12	−1.40	−2.02	−2.00	−1.78	+0.24	−2.16	−2.33	−2.38	−2.45	−2.70
45	White Thompson 5241	M. T. S.	O. S.	20.33	33.6	−1.04	0.00101	+1.82	+0.62	−0.54	−0.62	+0.36	+2.54	+0.29	+0.23	+0.17	+0.38	−0.24
46	Bond 597	M. T. B. C.	O. S.	20.40	65.2	+0.07	0.00198	+0.84	+0.26	+0.32	+0.22	+0.08	+1.72	+0.91	+0.63	+0.90	+0.80	+0.80
47	Glover 306	M. T. H.		20.51	56.4	+0.81	0.00191	+2.74	+1.48	+0.92	+0.70	+1.12	+3.18	+1.44	+0.99	+1.23	+1.03	+2.19
48	Negus 2233	M. T. S.	O. P.	21.05	47.6	−2.11	0.00067	−0.38	−1.52	−2.10	−2.04	−1.86	−1.42	−2.51	−2.42	−2.65	−2.63	−2.69
49	Nardin 1827	M. T. S.	V. S.	21.42	86.6	+0.75	0.00042	+0.16	+0.52	+0.32	+0.34	+0.82	+1.34	+0.81	+0.54	+0.60	+0.57	+0.66
50	Ainsley K/6036	M. T. S.		21.77	80.7	−0.63	0.00218	[illegible]0.00	−0.54	+0.80	+0.84	−0.42	−0.88	−0.56	−0.56	−0.63	−0.78	−0.69
51	Bliss 3196	M. T. S.	O. P.	22.20	56.0	−2.26	0.00015	−2.32	−2.12	−1.52	−2.20	−2.32	−2.66	−3.00	−2.88	−3.30	−3.25	−3.39
52	Sewill 1195	M. T. H.	O. S.	22.30	72.9	−1.27	0.00230	−0.36	−1.30	−0.50	−0.56	−1.24	−0.84	−1.79	−1.82	−2.45	−2.27	−2.57
53	Clerke 1710	M. T. S.		23.58	94.0	−1.23	0.00146	−1.58	−0.66	+0.94	+1.02	−0.46	−0.84	−0.06	−0.12	0.00	−0.33	−0.57
54	Geessler 1064	M. T. H.		23.72	69.6	−0.91	0.00188	+0.38	−0.80	−0.48	−0.52	−0.98	−0.64	−0.41	−0.56	−0.04	−0.28	−0.16
55	Negus 1754	M. T. B. C.	O. P.	24.03	62.2	−1.43	0.00261	+0.58	−1.08	−1.26	−1.32	−1.22	+0.60	+1.90	+1.33	+1.18	+1.39	+1.59
56	Parkinson Fordsham 2847	M. T. H.	O. S.	24.32	66.5	−0.03	0.00321	+1.62	+0.30	+0.58	+0.22	−0.12	+1.88	−0.47	−0.59	−0.58	−0.55	−0.71

57	Negus	1259	M. T. S.	O. S.	24.43	70.5	−2.23	0.00379	−0.76	−2.12	−3.20	−2.90	−2.20	−0.70	−2.50	−2.63	−1.85	−1.80	−2.36
58	Bond	585	M. T. B. C.	O. S.	24.82	74.5	−0.72	0.00323	+0.22	−0.74	+0.34	+0.68	−0.68	−0.12	+0.07	−0.43	+0.07	−0.18	−0.41
59	Fosler	266	M. T. H.	....	25.61	73.3	+0.63	0.00361	−0.46	+0.52	−0.54	−0.60	+0.74	−0.30	+0.29	0.00	−0.27	−0.22	−0.31
60	Sewill	4753	M. T. H.	O. S.	25.89	64.7	+0.57	0.00280	+2.56	+0.42	+0.84	+0.64	+0.88	+2.00	+0.34	+0.39	+0.05	+0.23	+0.04
61	Bond	509	M. T. S.	O. S.	26.70	70.1	−0.86	0.00387	+0.44	−0.74	0.00	+0.04	−0.94	+0.90	−0.13	−0.26	−0.08	−0.17	+0.14
62	Bond	1026	M. T. H.	O. S.	26.73	87.3	−1.15	0.00204	−1.32	−2.02	−0.10	−0.08	−1.16	−1.00	−1.14	−0.88	−1.16	−1.27	−1.36
63	Riggs	5115	M. T. H.	O. S.	26.74	49.7	−0.95	0.00193	+2.06	+0.06	−1.02	−0.78	+0.04	+2.30	−0.36	−0.49	−0.42	+0.18	+0.06
64	Bond	273	M. T. S.	O. S.	26.83	61.3	−2.77	0.00190	−1.32	−2.70	−2.70	−2.70	−2.36	−1.08	−2.51	−2.86	−3.37	−3.25	−3.31
65	Boeraud	2⁄89	M. T. H.	O. S.	26.92	70.2	−3.16	0.00294	−2.20	−2.88	−2.48	−2.48	−3.40	−1.80	−2.73	−2.88	−3.12	−3.20	−3.46
66	Kurtz	143	M. T. S.	V. S.	27.32	63.4	−0.97	0.00131	+1.04	−0.30	−0.24	−0.78	0.00	+0.98	−2.40	−1.69	−1.92	−1.72	−2.20
67	Negus	1969	M. T. S.	O. S.	27.55	77.2	+0.40	0.00098	+1.10	+1.68	+0.64	+0.50	+0.38	+0.68	+0.41	+0.06	+0.13	0.00	+0.10
68	Bliss	3077	M. T. S.	V. S.	27.70	45.2	+0.03	0.00074	+1.46	+1.10	−1.02	−1.04	+0.06	+1.64	+0.83	+0.30	+0.52	+0.28	+0.09
69	Bond	1018	M. T. H.	O. S.	28.21	68.4	−0.66	0.00173	+0.78	−0.50	−0.36	−0.34	−0.76	−0.48	−0.56	−0.73	−0.65	−0.87	−0.57
70	Kurtz	136	M. T. S.	V. S.	28.27	113.1	−2.18	0.00036	−1.28	−1.78	−1.04	−0.90	−1.40	−2.70	−1.83	−1.48	−0.88	−0.87	−0.69
71	Parkinson Fordsham	2514	M. T. H.	O. S.	28.89	55.4	−0.97	0.00292	+0.68	−1.78	−2.68	−2.66	−1.86	+0.96	−2.23	−2.39	−2.58	−2.62	−2.71
72	Bond	455	M. T. S.	O. S.	29.31	34.7	+2.26	0.00086	+2.64	+1.52	+0.30	+0.20	+0.54	+2.24	+0.76	+0.26	+0.27	+0.22	+0.41
73	Hutton	318	M. T. H.	O. S.	29.39	77.0	+1.10	0.00117	+1.28	+1.34	+2.36	+2.06	+0.96	+1.70	+1.69	+1.59	+2.33	+1.98	+2.36
74	Reid	1211	M. T. H.	....	29.71	64.5	+0.25	0.00186	+1.30	+0.30	+0.12	+0.72	+0.44	+1.62	+0.63	+0.66	+0.67	−0.03	−0.06
75	Barraud	1942	M. T. S.	O. S.	31.96	70.7	−0.65	0.00372	+0.32	−0.58	+0.32	+0.22	−0.70	+1.14	−0.57	−0.71	−0.73	−0.97	−0.93
76	Knoblick	2459	M. T. S.	O. P.	32.21	90.0	+1.42	0.00122	+1.48	−0.10	0.00	−0.34	+0.40	+0.96	−0.17	+0.43	+0.47	+0.97	+0.64
77	Bond	272	M. T. S.	O. S.	32.44	72.5	−1.30	0.00372	+0.06	−0.84	−0.20	−0.12	−1.76	−0.38	−0.96	−0.83	−0.97	−1.02	−0.94
78	Johannsen	4599	M. T. S.	Aux	33.16	79.0	−0.79	0.00057	−0.58	−0.98	−1.82	−0.44	−0.66	−1.14	−0.94	−0.62	−0.62	−0.68	−0.73
79	Fletcher	2544	M. T. H.	....	33.22	66.7	−0.49	0.00233	+0.58	−0.88	−0.50	+0.16	+0.06	+0.98	−0.57	−0.51	−0.70	−0.47	−0.96
80	Hutton	314	M. T. H.	O. S.	33.44	77.2	−0.98	0.00351	−0.40	−0.70	+1.10	+0.42	−1.10	−0.42	−0.39	−0.36	−0.37	−0.03	+0.64

ANNUAL REPORT OF THE

NAVAL OBSERVATORY

FOR THE

FISCAL YEAR 1930

UNITED STATES
GOVERNMENT PRINTING OFFICE
WASHINGTON: 1930

REPORT OF SUPERINTENDENT OF NAVAL OBSERVATORY

NAVY DEPARTMENT,
UNITED STATES NAVAL OBSERVATORY,
Washington, D. C., July 1, 1930.

From: Superintendent Naval Observatory.
To: Chief of Bureau of Navigation.
Subject: Report of the Superintendent Naval Observatory for the fiscal year ending June 30, 1930.

1. The following annual report on the Naval Observatory's eighty-sixth year of active operation—the fiscal year ending June 30, 1930—is submitted:

Previous annual reports have dealt at considerable length with the mission and the resulting functions of the various task groups of the observatory. These in turn were followed by very complete descriptions of the general plans of work, fields of effort, astronomical investigations to be made, services to the Navy and to the country to be rendered, books to be published, etc. The various major and minor tasks were then described in detail.

2. As all these are practically of a permanent character, and assuming that the information regarding them is now a matter of common knowledge, this year's report—in the name of economy—will be reduced to the bare statement of work undertaken, results accomplished, and summaries.

3. Various observatories, either university or privately endowed, are, with few exceptions, devoting themselves to important and valuable astrophysical work or to short specialized series of observations. The concentration of national observatories on the astronomy of position and the international coordination of their work therefore assumes added importance. The continuous observation programs must be carried out, as it is upon the data so collected that star catalogues are produced and the accuracy of future publications guaranteed.

4. The derivation and the broadcasting of the correct time is another of the observatory's most important tasks. The far-reaching effects of this duty can not be overestimated. The necessity for more modern precision clocks has long been recognized, and it is hoped that before long the observatory will be equipped with the most modern type.

5. The outstanding needs of the observatory have long been the subject of discussion. It is hoped that in the near future the discussions will bear fruit and our needs will be supplied. It is needless to add that too great economy in astronomical appropriations causes a corresponding reduction in output.

EQUIPAGE DIVISION

[Commander S. F. Heim, United States Navy, until June 10, 1930; Commander A. G. Stirling, United States Navy, after June 10, head of division]

Plans for changes in spyglasses have been prepared.

Reconditioning of all stock 6 by 30 binoculars has been completed. Work is now progressing on a supply of optical parts for these glasses, to be used as replacements for the large number of 6 by 30 power reconditioned glasses now in the service. These parts will be stored at the Naval Observatory.

The development of 7 by 50 binoculars, at the optical shop, navy yard, Washington, was continued. A number of these binoculars will be completed by June, 1931. The optical shop will then be able to manufacture this type.

Hoey position plotters have been placed on the allowance list as an optional title C article for all vessels.

Eight hundred Zeiss 7 by 50 binoculars were purchased during the year.

Sixty patrol boat chronometers were converted into second-setting navigation watches.

One improved type of Davis-Radford sextant has been sent to a cruiser for test and report. Delivery of three more of this type sextant for surface navigation is expected within the next month. Accuracy obtained with bubble sextants on surface vessels is disappointing. It probably will be some time before a satisfactory bubble sextant is produced.

Amendments to specifications for: Lines, cotton, braided; holders (brass tube) for sounding machine; high-grade sextants; surveying sextants; stadimeters and surveying instruments have been submitted to the specification board. Revised and new specifications have been submitted for the following: Instruments, drawing (Bureau of Navigation); psychrometers and cases; binocular, prismatic, 7 by 50 power, and anemometer, 3 cup knot and 1/10 knot type and its component parts.

N. Nav. 165 form has been revised to date of May, 1930, and is in process of being printed.

Aeronautical section.—Chief Aerographer F. G. Williams, United States Navy, has charge of this section of the equipage division. Lieut. T. C. Lonnquest, United States Navy, of the Bureau of Aeronautics, is the liaison officer in the continuous cooperative work between the observatory and that bureau. The observatory has continued experiments and research work in design, development, and improvement of aeronautical material.

The Mark IV airplane compass, developed after the experimental models were constructed by the observatory, meets the requirements of the service. During the year the observatory has continued the assembly of this type of compass for distribution to the service, as well as to manufacturers for installation on new airplanes purchased. Receipt, inspection of the necessary parts for assembly, and distribution of approximately 1,200 compasses has been accomplished.

Recently the observatory received six new design dash-mount airplane compasses which have not yet been tested.

During the year the observatory received 10 of the new design Bumstead sun airplane compasses, some of which are now in service use.

The Mark II, model 2, aeronautical bubble octant is yet in the experimental stage. From time to time throughout the year the contractor submitted these instruments for inspection. After each test it was found that the instruments failed to meet the specification requirements. Lengthy correspondence and discussions verified the observatory's position. After the contractor embodied such improvements, this fiscal year closed with the acceptance of three of the instruments. They are now in service use for test purposes. In connection with this type octant, the observatory has throughout the year experimented with rheostats, to obtain varying degrees of light, for night use of the bubble feature. It is believed that a suitable rheostat will be developed in the near future. The observatory also developed an experimental handle bracket for this type octant.

Mark IV drift computers, scouting plane type chart boards, Mark I, model 4, aeronautical octants, airplane clocks, and other air navigational material were inspected at the observatory during the year.

Flight test barographs, special flight test and other aviation watches, have been inspected at the observatory.

The observatory continued developing the metallic pilot balloon plotting board. A lighter design spider base has been constructed. A new track, developed from experience in service test, has been adopted. A number of metallic rules for horizontal distance and velocity have been constructed at the observatory. Considerable difficulty has been experienced in obtaining a suitable metallic disk for the face of the board answering the requirements and also withstanding the corrosion effect to which the disk will be subjected when exposed to salt air. The observatory is experimenting along this line, and a solution of the problem is hoped for.

The current supply unit and sea-water thermometer developed for the Bureau of Aeronautics at the observatory meets the requirements of the service, and has been produced and supplied by the observatory.

A lighter pilot balloon balance, for use with the ceiling balloon, was produced by the observatory and supplied to the service.

Five of the total of 15 new smaller and lighter design shore type theodolites have been received and inspected at the observatory.

The observatory continued to receive and inspect, for the Bureau of Aeronautics, aerological instruments and supplies. It also continues to test and calibrate thermometers, psychrometers, and sea-water hydrometers.

The observatory constructed a special testing stand and chamber for the test and inspection of thermometers and psychrometers.

The Naval Observatory continued correspondence of the Bureau of Navigation in regard to the design, procurement, and inspection of aerological, aeronautical, and aviation compass material in cooperation with the Bureau of Aeronautics. It continued supplying, overhauling, and repairing aerological and aeronautical instruments and supplies held in store at the Naval Observatory, as requested by the Bureau of Aeronautics.

The observatory maintained constant touch with sources abroad, to obtain the latest knowledge regarding the development of aeronautical instruments outside of the United States.

COMPASS DIVISION

[Commander R. Dudley, United States Navy, head of division]

The compass office procures and supplies gyro and magnetic compass equipment and all related articles to naval vessels. It also controls the repair, upkeep, and inspection of this equipment.

The following items are of interest:

Magnetic compasses.—Efforts were continued to obtain a petroleum distillate suitable for replacing the alcohol-water solution in ships' magnetic compasses. Recent tests conducted by the engineering experimental station, Annapolis, indicate that a satisfactory distillate has been found that will not change color when exposed to sunlight. Preparations are being made to test samples of the oil in compasses under service conditions.

A magnetic compass repeater system is being developed by a commercial concern. Preliminary drawings and a description of the proposed system have been submitted. It is believed that the system is adaptable for use aboard ship and in aircraft. A magnetic repeater system with course indicators at all steering stations will permit the elimination of magnetic steering compasses on battleships and cruisers. The transmitter for the repeater system is designed for mounting as an attachment to the Navy standard 7½ compass.

Telescopic alidades.—Twelve of these instruments have been in use aboard vessels of the fleet for about one year. These instruments were developed and manufactured at the optical shop, navy yard, Washington. The design has been modified and improved in accordance with suggestions from vessels to which the original 12 instruments were assigned, and the yard is now manufacturing 150 additional instruments.

Periscopic alidades.—This instrument has been designed for mounting in the conning towers of the 10,000-ton light cruisers as a means of taking relative bearings from that station. The optical shop, navy yard, Washington, D. C., has developed the plans and is now constructing a sample instrument before proceeding with production.

Gyrocompasses.—During the past year, the first two gyrocompass equipments purchased under the more rigid fire control compass specifications, have been delivered, tested, and installed on the *Pensacola* and the *Northampton.* These compasses are the most accurate so far developed and are believed to be suitable for use with the fire-control system of battleships and cruisers for indirect fire. The errors of these compasses are such that their accurate determination requires special test equipment not at present available for use aboard ship. The sea-testing equipment previously used for a series of gyrocompass tests on the *Marblehead* in 1928 is now being improved and reconditioned by the Naval Research Laboratory for use in testing gyrocompasses after installation on board ship. The laboratory acceptance tests of gyrocompasses do not always assure that the equipments will operate under service conditions within the accuracy requirement of the fire-control system.

Self-synchronous alidades.—These instruments are a new development being installed on new construction and on vessels modernized. The main operating feature of the instrument is that it maintains the alidade telescope or a bearing circle on any set true bearing regardless of any changes in the ship's heading. It is also adapted for use in determining compass error by observations of stars or planets, in addition to sun observations.

Self-synchronous course recorders.—These instruments are also a new development. They indicate by a graph the compass course at each instant of time to an accuracy of one-tenth of a degree.

Arma dead reckoning tracer and latitude and longitude indicators.—These equipments have been supplied to, or are being purchased for installation on all battleships, light cruisers, and on the *Lexington* and *Saratoga*. These equipments have proved to be a reliable and accurate means of indicating and determining a vessel's track and dead reckoning position. The manufacturers of this equipment have recently suggested a lighter, less expensive, but slightly less accurate similar system for destroyer squadron and division leaders.

Repair facilities (ashore).—Effort is made to equalize the work load at the various navy yard gyro-repair shops by authorizing a limited amount of reconditioning and modification work on the early type gyrocompasses held in store for decommissioned vessels, and the manufacture of redesigned parts for compasses in service, in order that trained personnel in these shops may be employed during slack periods. This procedure is carried out mainly at navy yard, Norfolk, and at the navy yard, Puget Sound. The large Scoresby test stand built at the navy yard, New York, for the navy yard, Puget Sound, has been temporarily installed at the gyro laboratory in the New York yard, in order to expedite the acceptance tests of the large number of new gyrocompass equipments being delivered at this time. The east coast gyrocompass and nautical instrument repair shops, and the supply depots that carry in stock, navigational equipment, have been inspected and a report has been submitted covering recommended improvements and changes.

Gyrocompass repair facilities afloat.—During the past year the forces afloat have completed the removal of the gyrocompass equipments from 56 destroyers being decommissioned and have reinstalled these on the replacement vessels. The three new Sperry Mark IX gyrocompass equipments recently delivered have also been installed on the *Schenck*, *Dupont*, and *Taylor* by the gyro personnel of the *Whitney*.

The intercardinal swing built by the repair force of the *Dobbin* and installed on that vessel has proved very useful in connection with the repair and overhaul of destroyer gyrocompass equipments and has resulted in a marked decrease in the cost of navy yard gyrocompass repairs to vessels of Squadron 14. There are now 276 vessels in commission equipped with gyrocompasses. The vessels so equipped include all naval vessels, except small gunboats, inactive auxiliaries, seagoing tugs, and mine sweepers. It is proposed to gradually recondition and modernize the 40 gyrocampass equipments held in reserve at the navy yard, Norfolk, for decommissioned submarines for future installation on the destroyers remaining out of commission. The decommissioned submarines are all slated to be scrapped during the next two years.

Statistical data.—During the past year contracts have been awarded for new navigational equipment as follows:

Duplex gyrocompass equipments for the U. S. S. *Idaho*, U. S. S. *Mississippi*, U. S. S. *New Mexico*, U. S. S. *New Orleans*, U. S. S.

Portland, U. S. S. *Astoria*, U. S. S. *Indianapolis*, and U. S. S. *Minneapolis*.

Self-synchronous alidades for the U. S. S. *Augusta*, U. S. S. *Louisville*, U. S. S. *Chicago*, U. S. S. *Idaho*, U. S. S. *Mississippi*, U. S. S. *New Mexico*, U. S. S. *New Orleans*, U. S. S. *Portland*, U. S. S. *Astoria*, U. S. S. *Indianapolis*, and the U. S. S. *Minneapolis*.

Dead reckoning tracer equipments and latitude and longitude indicators for the U. S. S. *Idaho*, U. S. S. *Mississippi*, U. S. S. *Maryland*, U. S. S. *Utah*, U. S. S. *Marblehead*, U. S. S. *Cincinnati*, U. S. S. *Detroit*, U. S. S. *Trenton*, U. S. S. *Memphis*, U. S. S. *Milwaukee*, U. S. S. *Raleigh*, U. S. S. *Louisville*, U. S. S. *Chicago*, U. S. S. *Augusta*, U. S. S. *New Orleans*, U. S. S. *Portland*, U. S. S. *Astoria*, U. S. S. *Indianapolis*, and the U. S. S. *Minneapolis*.

New gyrocompass equipments have been installed on the following vessels: U. S. S. *Oklahoma*, U. S. S. *Nevada*, U. S. S. *Salt Lake City*, U. S. S. *Pensacola*, U. S. S. *Northampton*, U. S. S. *V-5*, U. S. S. *V-6*, U. S. S. *Schenck*, U. S. S. *Dupont*, and U. S. S. *Taylor*.

New installations of reconditioned gyrocompasses have been made on the following vessels not previously equipped: U. S. S. *Falcon*, U. S. S. *Widgeon*, U. S. S. *Pigeon*, U. S. S. *Ortolan*, U. S. S. *Chewink*, U. S. S. *Mallard*, and U. S. S. *Asheville*.

Installation of reconditioned gyrocompasses have been authorized on the U. S. S. *Tulsa*, U. S. S. *Sacramento*, U. S. S. *Jason*, and U. S. S. *Fulton*. These installations authorized will provide gyrocompass equipments for all vessels which are to be retained in commission, except small gunboats, inactive auxiliaries, and mine sweepers.

MAINTENANCE DIVISION

[Commander F. Slingluff, Jr., United States Navy, head of division]

The maintenance division's primary function is maintaining the supply of nautical instruments for the Navy, a function distinct from the actual acquisition of such material, which is accomplished through the regular supply channels of the service. It not only insures that new material is available, but that old material is kept in proper repair.

The time-service section is in this division because the upkeep and repair of chronometers and other precision timepieces is closely associated with certain of the auxiliary functions of the time service.

This division assists in the economical employment of the "Instruments and supplies" appropriation. Saving is experienced in the repair of precision timepieces. A surplus war stock of patrol-boat chronometers has been converted into second-setting navigational watches. A balanced work load for the repair shop is insured by establishing cordial cooperative relation with various Government activities requiring occasional precision repair work. This occasional work is not permitted to interfere with the repair shop's service to the fleet.

The supplying of navigational material to the fleet functions smoothly. During the last year the observatory was designated as the source of supply for all repair parts to navigational instruments, parts not listed in the Standard Stock Catalogue. This is advantageous because a stock of repair parts is required for the navigational instrument shop, and the personnel is available for the inspection of this highly technical material. In addition to the economy of purchasing in large lots, it provides for the prompt supply of needed parts by mail to all repair activities of the Navy.

Pay, miscellaneous, 1930, subhead No. 7 (Naval Academy)	$72. 18
Pay, miscellaneous, 1930, subhead No. 16 (Board of inspection and survey)	92. 01
Contingent expenses, Navy Department, 1930	51. 35
Ocean and Lake Surveys, Bureau of Navigation, 1930	2, 376. 20
Maintenance, Bureau of Yards and Docks, 1930	6. 71
Current and miscellaneous expenses, Naval Academy, 1930	36. 74
Organizing the Naval Reserve, 1930, subhead No. 17	292. 60
Contingent and miscellaneous expenses, Naval Observatory, 1930	766. 32
Observations, eclipse of the sun, Naval Observatory, 1930–31	119. 14
Ordnance and ordnance stores, Bureau of Ordnance, 1930, subhead No. 1	1, 968. 91
Construction and repair, Bureau of Construction and Repair, 1930	18. 37
Engineering, Bureau of Engineering, 1930, subhead No. 1	146. 60
Naval hospital fund (special fund), subhead No. 1	3. 94
Aviation, Navy, 1930—subheads Nos. 2, 3, and 6	5, 243. 31
General expenses, Marine Corps, 1930	15. 75
Department of Commerce Orders Nos. 10940, 30–2308, 30–12377, 30–8087, 30–6997, 30–14623, 30–16648	477. 03
Repairs to Coast Guard vessels, 1930	73. 06
U. S. Shipping Board, Merchant Fleet Corporation	72. 01
General expenses, public parks	31. 50
Total	11, 863. 73

Summary of work on instruments	1930	1929
(*a*) Timepieces of all classes and types	$1, 457. 00	$1, 090. 00
(*b*) Navigational and surveying instruments	2, 373. 00	4, 686. 00
(*c*) Aviation and aerological instruments	864. 00	558. 00
Value of stock on hand July 1, 1929	424, 344. 74	---------
Value of instruments, etc., purchases	146, 435. 41	---------
Value of instruments, etc., from stations and ships	125, 511. 24	---------
Total	696, 291. 39	---------
Value of instruments, etc.; issued and expended	248, 497. 63	---------
Value of stock on hand June 30, 1930	447, 793. 76	---------

	Navigational	Aeronautical	Total	Total last year
Number of shipments received	1, 302	318	1, 620	1, 324
Number of instruments and parts received	81, 616	42, 027	123, 643	58, 080
Number of shipments made	1, 038	899	1, 937	1, 361
Number of instruments and parts shipped	17, 999	28, 211	46, 210	31, 146

Value of instruments purchased and received from stations and ships per fiscal year:

Fiscal year—	
1925	$260, 129. 48
1926	259, 103. 01
1927	258, 071. 33
1928	362, 309. 92
1929	186, 245. 34
1930	271, 946. 65

Value of instruments issued and expended to stations, ships, etc. per fiscal year:

Fiscal year—	
1925	$193,467.86
1926	229,674.33
1927	1,406,979.35
1928	843,120.37
1929	212,625.01
1930	248,497.63

Time service.—Astronomer Paul Sollenberger continued as time-service supervisor throughout the year.

Time signals are broadcasted by the Naval Observatory via the naval radio stations at Arlington and Annapolis, as shown in the following table. During the transmission of time signals, these stations are controlled through a special telegraphic line from the Naval Observatory.

C. W. = Continuous waves.
I. C. W. = Continuous waves modulated at audible frequency.
G. C. T. = Greenwich civil time.
75 M. = Seventy-fifth meridian time.

Call	Location	Frequency	Wave length	Kind	Power	Signals ending at—		Dates
						G. C. T.	75 M.	
		Kilocycles	*Meters*		*Kilowatts*	*Hours*		
NAA	Arlington, Va.	113	2,655	I. C. W.	10	3	10 p. m.	Throughout year.
						8	3 a. m.	Do.
						17	Noon	Do.
		690	435	I. C. W.	1	3	10 p. m.	Do.
						17	Noon	Do.
		4,015	74.7	C. W.	10	3	10 p. m.	Do.
						17	Noon	Do.
		8,030	37.4	C. W.	10	3	10 p. m.	July 1, 1929, to Mar. 16, 1930, inclusive.
						8	3 a. m.	
						17	Noon	
		8,870	33.8	C. W.	10	3	10 p. m.	Apr. 18, 1930, to June 30, 1930, inclusive.
						8	3 a. m.	
						17	Noon	
		12,045	24.9	C. W.	10	3	10 p. m.	July 1, 1929, to Mar. 16, 1930, inclusive.
						17	Noon	
		16,060	18.7	C. W.	10	17	do	Mar. 17, 1930, to June 30, 1930.
NSS	Annapolis, Md.	17.8	16,855	C. W.	350	3	10 p. m.	Throughout year.
						8	3 a. m.	Do.
						17	Noon	Do.
		8,870	33.8	C. W.	1	3	10 p. m.	Some date in March and April, 1930.
						8	3 a. m.	
						17	Noon	
		12,045	24.9	C. W.	25	3	10 p. m.	Mar. 17, 1930, to June 30, 1930, inclusive.
						17	Noon	

The noon signals are distributed to nearly all parts of the country by the Western Union and Postal Telegraph Cos. A number of naval radio stations, listed below, transmit time signals the origin of which is indicated for each station. The notation is as follows:

W. U. = Controlled by Western Union lines during transmission of time signals. The time signals either originated at the Naval Observatory or were based on Naval Observatory time determinations.

M. I. = Signals based on time determinations made at naval time and chronometer station, Mare Island, Calif. The determination of time at this station has now been discontinued, and all time signals sent by naval radio stations in continental United States are now based directly or indirectly on Naval Observatory time determinations.

M. C. O. = Time signals originated at the Manila Central Observatory.

Rad. = Time signals sent by transmitting clocks at or near transmitting stations, which clocks were set after comparison with radio time signals sent by stations at Arlington, Annapolis, or Mare Island.

Call	Location	Frequency	Wave length	Kind	Power	Signal ending at—		Source	Dates
						G. C. T.	75 M.		
		Kilocycles	*Meters*		*Kilowatts*	*Hours*			
NAJ	Great Lakes, Ill.	122	2,459	ICW	1	17	Noon.	W.U.	Throughout year.
NAR	Key West	106	2,830	CW	2	17	do	W.U.	Do.
NAT	New Orleans	104	2,885	CW	1.5	17	do	W.U.	Do.
NAX	Colon, Canal Zone	132	2,273	CW	5	4	11 p. m.	Rad.	Do.
						18	1 p. m.	Rad.	Do.
NBA	Balboa, Canal Zone	46	6,522	CW	100	4	11 p. m.	Rad.	Do.
						18	1 p. m.	Rad.	Do.
NPE	Astoria, Oreg.	102	2,941	CW	2	17	Noon.	W.U.	Do.
NPG	San Francisco, Calif.	42.8	7,009	CW	100	6	1 a. m.	M. I.	July 1, 1929, t Feb. 19, 1930, inclusive.
						20	3 p. m.		
		66	4,545	CW	40	6	1 a. m.		
						20	3 p. m.		
		108	2,778	CW	.5	6	1 a. m.		
						20	3 p. m.		
		42.8	7,009	CW	100	6	1 a. m.	Rad.	Feb. 20, to June 30, 1930, inclusive.
						20	3 p. m.		
		66	4,545	CW	40	6	1 a. m.		
						20	3 p. m.		
		108	2,778	CW	.5	6	1 a. m.		
						20	3 p. m.		
NPL	San Diego, Calif.	30.6	9,804	CW	80	17	Noon.	Rad.	Throughout year.
		102	2,941	CW	2	17	do		
NPM	Honolulu, Hawaii	26.1	11,494	CW	350	24	7 p. m.		
		106	2,830	CW	2	24	7 p. m.		
NPO	Cavite, P. I.	56	5,357	CW	30	3	10 p. m.	MCO.	Do.
						14	9 a. m.		
		8,872	33.8	ICW	.25	3	10 p. m.		
						14	9 a. m.		
		17,744	16.9	ICW	10	3	10 p. m.		
						14	9 a. m.		
NPW	Eureka	108	2,778	CW	2	17	Noon.	W. U.	Do.

The 17.8-kilocycle Annapolis signal and the 113-kilocycle Arlington signal are automatically recorded on the chronograph as far as possible on all signals, so as to measure the actual times of emission from the radio stations. In addition, the 4,015-kilocycle Arlington signal was recorded at 3 hours, G. C. T., and the 8,030-kilocycle Arlington signal was recorded at both 8 hours and 17 hours, until March 16, 1930, when that frequency was discontinued. The 8,870-kilocycle signal was recorded at 8 hours, beginning April 18, and at 17 hours beginning May 13. The 16,060-kilocycle was recorded at 17 hours, beginning March 20. The time signals sent from Rugby, England (GBR), at 18 hours, and from Bordeaux, France (FYL), at 8 hours 6 minutes, were recorded on a majority of the dates throughout the year.

The maximum error of the time of emission of any signal from the Naval Observatory was $0^{s}21$ and the average error was $0^{s}038$. The errors of the times of emission from the radio stations were larger, owing to the lags of the transmission apparatus.

The board which met in the fall of 1928 for studying the time signal system, as explained in the last annual report, recommended a change in the time signal code so as to make possible the identification of each minute of the signal. As suggested by the board, this proposal was referred to the shipping interests, as well as other users of time signals. It was found that practically all users of radio signals were favorable to the change, although the telegraph companies were opposed on the grounds that it would require change in their equipment. The new code was accordingly approved and was put into effect at the Naval Observatory and at Honolulu, Hawaii, on March 9, 1930. Since that date the change has also been effected at San Francisco and Cavite, and it is anticipated that apparatus will be available at an early date for making the change in the control of the two stations in the Canal Zone. All reports which have been received since the new code went into effect have been very favorable.

For the recording of time signals an old style writing chronograph of one pen had been in use for a number of years. This was unsatisfactory for the work because it did not afford sufficient precision, because its record required too much labor in reading, and because one pen was inadequate for recording several radio stations together with the transmitting and standard clocks during the signals. Since no machine commercially available appeared to meet the peculiar needs of the time service, a new type of chronograph was designed by Mr. Sollenberger and constructed in the Naval Observatory shop. This machine prints five independent records simultaneously, and makes possible the reading of the time of any tick by inspection, without the use of a ruler. Although it is not yet complete in all respects, the chronograph has been in use for several months, and has made possible increased accuracy as well as speed.

While the policy of issuing time-signal corrections weekly has been adhered to as far as possible, it has been found that considerable difficulty exists in securing the speed which is desirable. The uncertainties of the weather cause inevitable delays, often of a number of days, in obtaining the number of observations after the close of a period that are necessary to compute definitive corrections. Some delay is also necessary for completing the computations and having the results mimeographed. The situation has been partly met by not adhering too rigorously to the weekly schedules, but issuing the corrections at such times as star sights made speed possible. In order to serve those who were desirous of utilizing the results sooner than is possible with the regular corrections, a new service has been inaugurated. The times of the signals, according to the standard clocks uncorrected by the results of time sights, are issued three times weekly to those who so desire.

The usefulness of the results are somewhat reduced by the rather poor running of the standard clocks. Their performance has also hampered the whole operation of time signal transmission. Steps are being taken to secure a new clock of more modern design, and it is hoped to replace all the Riefler clocks in a few years.

Experiments were conducted in the spring of 1930 to determine the feasibility of automatic reradiation of the Arlington high-frequency signals from Mare Island. This work resulted so successfully that it is planned to install the system for regular time signal transmission as soon as a suitable diversity receiver is available at Mare Island. The extension of such a method to other naval radio stations, including those controlled by Western Union and by secondary clocks, would reduce lags and greatly increase the accuracy of the time signals sent by the distant stations.

A trial of old chronometers was held during the year, beginning January 11, 1930, and ending March 25.

EPHEMERIS DEPARTMENT

[Head Astronomer James Robertson in charge]

Capt. W. S. Eichelberger, corps of professors of mathematics, continued as director of this department until September 18, 1929, when he was succeeded by Head Astronomer James Robertson.

The American Nautical Almanac for 1931 was received from the printer on December 30, 1929.

The American Ephemeris and Nautical Almanac for 1932 was received from the printer June 21, 1930.

The copy of the Ephemeris for 1933 is practically completed. A few pages await the arrival from Paris of the data concerning the satellites of Jupiter.

The copy of the American Nautical Almanac for 1932 has been completed.

In addition to the publications regularly issued, there has been published, as a supplement to the American Nautical Almanac, the Lunar Ephemeris for Aviators, designed to enable a navigator to quickly reduce simultaneous observations of the sun and moon to determine his position. Four numbers of this publication have been completed, giving the data from September 1, 1929, to December 31, 1930. These data for 1931 will be issued in one volume, and for 1932 and subsequent years, it is proposed to include the matter contained in this supplement in the regular editions of the American Nautical Almanac, with such changes as experience may suggest.

The Ephemeris list of stars was increased by 36, making a total of 851 stars of which the apparent places are given.

Corrections to the longitude of the moon were determined from occultations observed at the Naval Observatory, Union Observatory of South Africa, and the Tokyo Observatory of Japan, and the data for the eclipse of April 28, 1930, were revised.

Some time has been devoted to extending the star tables and revising the data necessary for producing the Ephemeris. This work had been discontinued a few years ago.

NINE-INCH TRANSIT CIRCLE DIVISION

[Principal Astronomer Dr. Herbert R. Morgan, head of division]

NINE-INCH TRANSIT CIRCLE

The program, purpose, and continuity are the same as stated in last year's report.

Work on the reductions of 72,330 observations made with this instrument from 1913 to 1926 has been continued throughout the year. The reductions to mean place have been finished, the observations all collected on the card catalogue, reduced to equinox, the means taken, and the systematic corrections entered. The precessions have all been computed, and the secular variations are partly computed. The probable errors have been computed, and for all residuals larger than four times the probable error the reductions of the observations have been rechecked.

A thorough investigation has been carried out for corrections to the polar and Equator points, the refraction, and the flexure, including discussions of the circumpolar observations and of the observations of the sun, moon, and planets, and a comparison of the observed position of some 2,500 standard stars with the positions of these stars in the Second Cape Fundamental Catalogue, 1900, in the San Luis Catalogue, 1910, and in the General Catalogue of Boss. The observations of the sun, moon, and planets have been completely reduced and have been discussed for equinox and Equator, and for certain corrections to tabular elements.

The discussions of these observations have furnished additional information applicable to a revision of the reductions of the previous observations on this instrument from 1903 to 1913. (Cat. 1900.) More definitive results are to be given later, but provisional comparisons with standard catalogues of the fundamental declinations from the present catalogue (1919), and from the revision of the previous catalogue (1907), are given in the accompanying table, where the comparison catalogues are: Eichelberger; Newcomb; the revision of Boss (A. J. No. 884); and the revision of Auwers (A. N. No. 5591).

Washington minus catalogue, declination

	W (1919)				W (1907)			
Decl.	Ei.	N.	Bv.	Av.	Ei.	N.	Bv.	Av.
+85°	−.″03	−.″03	−.″06	−.″09	−.″07	−.″10	−.″08	−.″10
+75	+.10	+.22	+.05	+.03	−.02	+.05	−.04	−.06
+65	+.09	+.18	+.01	+.03	−.11	−.03	−.15	−.13
+55	+.01	−.12	+.08	+.08	−.19	−.23	−.09	−.09
+45	−.05	+.04	+.11	+.09	−.09	−.03	+.02	.00
+35	+.14	+.24	+.24	+.26	−.09	−.12	−.05	−.03
+25	.00	+.18	+.16	+.13	−.11	.00	−.01	−.04
+15	−.10	+.22	+.20	+.17	−.05	+.13	+.14	+.11
+5	−.17	−.08	+.09	+.08	−.10	−.06	+.08	+.07
−5	−.15	−.14	+.03	+.09	−.11	−.11	+.04	+.10
−15	−.17	−.17	−.05	+.04	−.20	−.20	−.11	−.02
−25	−.30	+.01	−.14	−.15	−.23	+.06	−.11	−.12

It is seen by the above that the declination system of this instrument agrees closely with the fundamental catalogues, and their revisions using modern observations.

A discussion of the declinations of the circumpolar stars observed with this instrument from 1903 to 1925 has been made with the resulting value of the aberration constant of 20.″479 ± 0.″008.

The observations of the moon and five outer planets taken with this instrument from 1894 to 1925 have been collected, reduced on uniform bases, and published.

SIX-INCH TRANSIT CIRCLE DIVISION

[Principal Astronomer J. C. Hammond, head of division]

SIX-INCH TRANSIT CIRCLE

The program, purpose, and continuity are the same as stated in last year's report.

Observations of the sun, moon, and planets were continued through the year. The observations of the zodiacal stars were completed on

May 26, and observations of the standard stars were begun on April 10. Observations of the Eros comparison stars in list 2 were resumed in March, and 119 more of these stars were observed, 115 twice each and 4 once each. The minor planets Ceres and Vesta were observed for periods of five and three months, respectively. Observations of standard stars near the zenith furnish additional data for use of the time service.

The number of observations made during the year is as follows:

Sun	173	Vesta	19
Moon	113	Clock stars	3, 042
Mercury	69	Azimuth stars	319
Venus	104	Refraction stars	295
Mars	0	Zodiacal stars	5, 537
Jupiter	16	Standard stars	1, 072
Saturn	10	Eros stars	231
Uranus	16		
Neptune	7	Total	11, 050
Ceres	27		

The observations are reduced through apparent place to March 12, 1930, and the mean place reductions to 1925 for the zodiacal stars are completed to January 23, 1930. The results of the observations of the moon made with this instrument in the years 1925 to 1929 inclusive, were published in Astronomical Journal 939; the observations of the major planets for the same period have been sent to the Journal for publication.

New lamp holders for the eight microscopes of the instrument were installed in November and have proven entirely satisfactory. The light on the circle under each microscope is diffused from a mat surface of plaster of paris near the circle so that no troublesome reflected light enters the microscopes. The holders were made in the nautical instrument repair shop.

A new 10-column Burroughs adding and listing machine and a new 10-place Millionaire with keyboard and electric drive were purchased during the year for use in this division.

More extensive manuscript tables have been made for facilitating the derivation of star constants for the reduction from apparent to mean place in accordance with a method devised by Astronomer J. E. Willis. By this means a saving of more than 2,000 hours of computing has resulted in the last two years.

Printer's copy is being prepared for a book of tables for reducing transit circle observations

In June an apparatus, constructed in the nautical instrument repair shop, for measuring the flexure of the tube and optical system of the transit circle, was mounted on the instrument. This apparatus is similar to that designed and used by Bousdorff of the Pulkowa Observatory in 1914 (Bulletin of the Pulkowa Observatory, Vol. VI, p. 105) except that it can be used for measuring flexure in right ascension, as well as in zenith distance. It consists essentially of four steel tubes firmly attached to the cube, parallel to the optical axis and supporting in front of the objective a rectangular aluminum frame perpendicular to the optical axis. This frame carries a flat mirror with which reflected images of the threads are formed. The tubes and frame are connected by accurate bearings so that small flexures of the steel tubes should only cause the plane mirror to move parallel to itself without diplacing the images of the threads. An examination of the relative positions of the threads and their reflected images in various positions of the transit circle reveals the flexure of the tube and optical system of the instrument.

A series of measures made with this apparatus shows that the measured flexure of the instrument affecting the declinations varies uniformly with the zenith distance, having the form a sin z + b sin 2z, and giving as the horizontal flexure nearly the same value as determined by the opposing horizontal collimators; that the flexure affecting the right ascensions is nearly inappreciable, indicating that the source of the known flexure in right ascension as exhibited by clamp differences must be in the axis of the instrument.

Experiments with electrically driven pendulums have been carried out, with the general purpose of determining the causes which limit the accuracy of pendulum timekeepers and of directing attempts to improve the timekeeping qualities of pendulum clocks.

The stellar focus was adjusted three times—on November 16, April 11, and June 12.

The instrument was reversed 28 times, and the number of determinations of its instrumental constants is:

Collimation	352	Azimuth from marks	909
Level	926	Nadir	1,086

CLOCK VAULT

The temperature in the clock vault was maintained practically constant at 84° F. during the year. Riefler No. 60 ran satisfactorily throughout the year. Riefler No. 70 (used as standard clock) has been running satisfactorily since March 1928; the mean daily rates show a systematic annual variation of about 0.07 second. Riefler No. 151 was dismounted in July for certain adjustments in an attempt to improve the running. A small mirror was attached to the pendulum rod for later use in connection with a photoelectric contacting equipment. The photoelectric equipment for taking the beats directly from the pendulum was attached to the pier of Riefler No. 151 in February, and was found to perform accurately to the thousandth of a second. The individual mechanical contacts of the Riefler clocks vary over several hundredths of a second. Riefler No. 151 was again dismounted and overhauled in April. The hands and parts of the train were restored and certain adjustments were made before it was again set up in the vault.

The following table indicates the performance of the three Riefler clocks in the vault:

	No. 60		No. 70		No. 151	
	Mean daily rate	Maximum variation	Mean daily rate	Maximum variation	Mean daily rate	Maximum variation
1929	*Second*	*Second*	*Second*	*Second*	*Second*	*Second*
July	−0.16	0.02	−0.02	0.02	--------	--------
August	.17	.01	.04	.02	+0.01	0.16
September	.18	.03	.04	.04	−.09	.04
October	.17	.02	−.02	.04	.15	.06
November	.17	.02	+.01	.04	.19	.02
December	.15	.01	.05	.02	.16	.08
1930						
January	.16	.01	.04	.01	.18	.04
February	.17	.01	.04	.06	.14	.27
March	.18	.01	.06	.01	−.12	.15
April	.18	.01	.05	.02	--------	--------
May	.20	.04	.03	.02	−.05	.10
June	−.20	.02	+.02	.01	−.02	.10

ALTAZIMUTH AND ZENITH TUBE DIVISION

[Capt. F. B. Littell (Math.), United States Navy, head of division]

ALTAZIMUTH

The program, purpose, and continuity are the same as stated in last year's report.

The plan of work for the altazimuth comprises declination observations of the Sun, Mercury, Venus, Ceres, and Vesta, and of the stars of the list in Volume X, Part I, Astronomical Papers of the American Ephemeris and Nautical Almanac, being observed simultaneously with the 6-inch transit circle. Observations during the year were as follows:

Sun	162
Mercury	37
Venus	99
Ceres	9
Vesta	8
Stars	1, 732
Total	2, 047

PHOTOGRAPHIC ZENITH TUBE

The program, purpose, and continuity are the same as stated in last year's report.

Observations with the zenith tube have been continued as usual. Approximately 2,036 stars on 311 plates were secured. The results of the observations for the year 1928.0—1929.0 have been published in the Astronomical Journal.

EQUATORIAL DIVISION

[Principal Astronomer H. E. Burton, head of division]

TWENTY-SIX-INCH EQUATORIAL

The program, purpose, and continuity are the same as stated in last year's report:

Observations were made as follows:

Satellite VI of Jupiter	4
Satellites of Saturn:	
(Rhea-Titan)	32
Asteroids:	
1 Ceres	3
2 Pallas	7
4 Vesta	3
Comets:	
Wilk (1929d)	4
Beyer (1930b)	1
Schwassmann-Wachmann (1930d)	4
Occultations	32
Eclipses of satellites of Jupiter	5
Double stars	72
Stars	140
Pluto	4

There were visitors on 95 nights. The total number of visitors was 863.

Most of the observations of stars were made in connection with the determination of the differences in right ascension and declination between faint stars difficult to observe with the 6-inch transit circle and brighter stars which could be observed with that instrument.

Four new positive eyepieces made at the United States Naval Gun Factory optical shop by Dr. Max Zwillinger have been received. They are designated as Schroeder 19.19, Hastings 20.19, Schroeder 25.87, and Zwillinger 29.68, where the number indicates the focal length of the equivalent lens in millimeters. The Schroeder and Hastings eyepieces are composed of three cemented lenses and two cemented lenses, respectively. The Zwillinger eyepiece is composed of three pairs of cemented lenses.

A new lamp holder was attached to the instrument so that a 6-volt 21-candlepower lamp could be used for field illumination. With this lamp the field can be made bright enough for an eyepiece magnifying one thousand seven hundred and sixty-seven times, the highest power provided for the instrument. Formerly a power of 800 was about as high as could be used with field illumination.

A new electric motor developing one-fourth horsepower from a 110-volt circuit and switch for operating the dome with remote control at the eye end of the telescope were installed.

A Hartmann test of the objective was made with iso-chromatic photographic plates and a "minus blue" color filter.

An aluminum dew cap lined with felt was attached to the telescope.

The Repsold micrometer was overhauled and cleaned.

TWELVE-INCH EQUATORAL

The program, purpose, and continuity are the same as stated in last year's report.

With this instrument were observed 10 occultations and the first contact of a solar eclipse.

There were 2,824 visitors. Various members of the staff participated in showing visitors.

Volume XII of Publications of the United States Naval Observatory, Second Series, containing the equatorial observations of 1908–1926, except a few observations made in 1908 and published in Volume VI, has been issued by the United States Government Printing Office.

During the past three years a course of instruction in field astronomy for postgraduate students from the Naval Academy has been conducted by this division. The work consists principally of making and reducing observations for the determination of the clock correction with the Stackpole transit instrument, the determination of latitude by Talcott's method, and the determination of the azimuth of a mark with the surveyor's transit from observations of the sun and Polaris. Fourteen officers, including three from the Chinese Navy, have taken the course this year.

ASTROGRAPHIC DIVISION

[Principal Astronomer George H. Peters, head of division]

PHOTOHELIOGRAPH

The program, purpose, and continuity are the same as stated in last year's report.

Observations of the sun were made with the photoheliograph on 308 days. Solar spots or groups were found on all these plates.

As predicted in the annual report for 1929, a secondary maximum or increase in mean daily spot areas occurred during a portion of the year.

The graph of the sun-spot curve, published in the last annual report, has been extended. This graph is compiled from mean daily areas, taken monthly, as derived from the Naval Observatory observations, and in case of clouds those of the cooperating observatories mentioned later. It is likely that the sun-spot curve will now gradually decline until 1933 or early in 1934, when a normal minimum should occur.

Publication of current solar observations in the Monthly Weather Review, begun in January, 1927, has been continued. On dates when observations are impossible, on account of weather conditions at the Naval Observatory, such solar data have generally been supplied by the Yerkes Observatory, the Mount Wilson Observatory, the Astronomical Laboratory, Harvard College, or the Perkins Observatory of the Ohio Wesleyan University. The cooperation of the last-mentioned observatory was secured during the present fiscal year.

Through the wide geographical distribution of the cooperating observatories, daily solar observations are but seldom missing in this country, but four days being thus missed during the present fiscal year. The number of days when solar photographs have been made at the Naval Observatory was greater in the present fiscal year than in any previous. In the last fiscal year, an unusually good one, the number was 297 days, while during the current period it was 308.

A conference was held with officials of the Bell Telephone laboratories at the Naval Observatory on April 26. This conference resulted from inquiries regarding solar data, and its influence, with respect to their investigations. Advance information by post card regarding solar conditions is now being furnished to these laboratories and also to the Western Union Telegraph Co. as in previous years. In cases of unexpected or unusual solar phenomena, immediate telegraphic or telephonic information is supplied these companies.

The Bell Telephone laboratories are furnishing reports of disturbances on their experimental lines. Reports of the Western Union of a somewhat similar character have been furnished since 1921. These latter are based upon interruption to traffic on their land and cable lines. Efforts are being made to determine the nature of the solar phenomena responsible for disturbances on the lines of these companies and also with respect to radio transmission. Several disturbances of considerable magnitude have been reported during the past year. During the coming year, as indicated by the conditions of the sun-spot curve, magnetic conditions should be at least equally active.

Occasionally, on this post-card service, predictions have been made of magnetic disturbances about to happen, from observations of conditions on our solar photographs. Usually the prediction is verified in the subsequent reports received. Certain types of spots or groups when near the apparent center of the solar disc appear to produce these effects. This work of tentative prediction will be continued. The character of spots supposed to be connected with these disturbances is being analyzed.

TEN-INCH PHOTOGRAPHIC TELESCOPE

The program, purpose, and continuity are the same as stated in last year's report.

The following observations have been secured with this instrument:

	Observations
Asteroids (29)	45
Planet Neptune	12
Planet (Lowell) Pluto	3
6-inch transit-circle star list	15
Total	75

In April one of the 10-inch photographic lenses was removed from the instrument for further adjustment. Ports were cut in the tube to facilitate changes in the position of the middle lens of this triplet for making corrections to field. This correction is accomplished by altering distances while preserving collimation of this lens with respect to the other two. The operation can now be accomplished without removing the front element. The adjustment has not yet been completed, and the services of an optician may be necessary to obtain good definition over the field required.

The degree divisions of the declination circle have been renumbered and now read north polar distance. A small rheostat in the driving clock circuit has been installed on the tube of the telescope for making small adjustments in the rate of this electric clock from the eye end. A geared arrangement has been provided for operating the shutters of the 10-inch lenses by the turn of a handle, which prevents jarring the instrument when the shutters are manipulated. The nautical-instrument repair shop performed this work.

A series of improved photographs for a second Hartmann test of the 26-inch equatorial objective, using a color screen and orthochromatic plates, was secured in June. These negatives will be measured and discussed in the near future.

MISCELLANEOUS ITEMS

Plates of the total solar eclipse of April 28, 1930, secured by Mrs. Isabel M. Lewis at Honey Lake, Calif., were developed at the Naval Observatory. On account of thin clouds and the short duration of totality, the corona was not apparent on the negatives. The symmetrical position of the chromosphere and prominences, with respect to the moon, indicated the location selected, was close to the central line of the narrow shadow path. This prediction was by the ephemeris department of the Naval Observatory of which Mrs. Lewis is a member of the staff. Photographs of the partial phase of this eclipse for contact times were attempted with the photoheliograph at the Naval Observatory, but were unsuccessful on account of clouds.

VISITORS ON 12-INCH EQUATORIAL

During the fiscal year the observatory has been open to visitors, by card of admission, on Thursday evening, for views of interesting celestial objects through the 12-inch equatorial telescope. Lectures, including topics of popular astronomical interest, have been given in connection with the objects observed.

The number of visitors received on these regular evenings was 1,892 on 53 nights, 17 of which were cloudy.

In addition, 932 special visitors, including schools and out-of-town parties, were received on 40 nights.

The total number of visitors using the 12-inch equatorial was 2,824 on 93 nights.

COMPUTING SECTION

[Associate Astronomer Eleanor A. Lamson, supervisor of section]

The 9-inch transit circle division—Work has been done on the mean place reductions of stars from October, 1923, to July, 1925.

The 6-inch transit circle division.—Work has been done on the reductions of the right ascensions and declinations of the current observations, July, 1929, to July, 1930.

The altazimuth and zenith tube division.—Work has been done on the mean place reductions of stars observed with the altazimuth from May, 1916, to November, 1917, and from June, 1928, to March, 1930, and of stars observed with the photographic zenith tube from June, 1929, to April, 1930.

The astrographic division.—Work has been done on the preparation of sun-spot data for publication in the Monthly Weather Review, and on the reduction of asteroids observed with the photographic equatorial in the fall of 1929.

Prime vertical observations, 1921–1925.—The formation of the catalogue from these observations and the discussion of the results are nearing completion.

Printing.—The remainder of the proof of Volume XII, including appendix, was edited.

The Appendix I, Volume XIII, on "The Gravity Measuring Cruise of the U. S. submarine *S–21*" was prepared by the collaboration of Dr. F. A. Vening Meinesz, of the Netherland Geodetic Commission; Dr. F. E. Wright, of the Carnegie Institution, of Washington; and Miss Eleanor A. Lamson, of the United States Naval Observatory. The material is now in the hands of the printer.

LIBRARY

[Grace O. Savage, librarian]

Until the appointment of the librarian last August, the library had been without a head for more than two years. Efforts to make this valuable collection more useful to readers and research workers have been continuous. Library of Congress methods of classification and cataloguing have been adopted and important indexes to current books and periodicals have been obtained to make scientific literature readily available. About 4,000 Library of Congress printed cards, author, subject, and title, have been substituted for cards of the old author catalogue. This library is now cooperating with the Library of Congress by furnishing copy for printed catalogue cards, on request, in exchange for the finished printed cards needed for added entries.

In addition to the regular work of making bibliographical lists, recording, filing, classifying, cataloguing, preparing books for binding, reference work, book selection, and distribution of Naval Observatory publications, several hours have been given to the checking of entries in the Union List of Serials in order that this library may be represented accurately in the new edition.

The library has been open three evenings during the year to receive visitors, once on Navy Day and twice to entertain members of the District of Columbia Library Association. On two of these occasions exhibits were arranged to show the history and development of the work of the observatory and to show some of the valuable books in this library. Some of the old books have been placed in museum cases for display.

The most noteworthy gift for the year was the Asaph Hall, jr., library of about 625 volumes, which contains many books accumulated by his father, Asaph Hall, sr. This valuable collection was presented by Mrs. Asaph Hall, jr., and her daughters. These books will be used as a reference collection.

The present weeding out of extraneous material and the building of shelving in two small basement rooms will soon allow space for the library to be shelved properly but will not allow for future growth.

Annual report United States Naval Observatory library

	Purchase	Gift	Exchange	Total
Accessions:				
Books	72	701	63	836
Periodicals	1,507	41	2,412	3,960
Total	1,579	742	2,475	4,796

Circulation:	Copies
Books loaned	935
Periodicals loaned	852
Total loaned	1,787
Total returned	1,759
Interlibrary loan:	
Borrowed from other libraries	70
Circulated to staff	98
Returned to other libraries	65
Loaned to other libraries	66
Returned from other libraries	56

Naval observatory publications

	Copies received from printer	Copies distributed
Annual report, 1929	1,100	831
Publications, second series, Vol. XII	800	656
American Ephemeris:		
1930		261
1931	1,500	550
1932	1,500	
American Nautical Almanac:		
1930		1,551
1931	3,300	465
Lunar Ephemeris:		
Sept. 1 to Dec. 31, 1929	1,800	1,712
Jan. 1 to Apr. 30, 1930	1,800	1,093
May 1 to Aug. 31, 1930	1,800	1,213
Miscellaneous		457
Total	13,600	8,789

PUBLICATIONS OF THE OBSERVATORY

Volume XII, Publications of the United States Naval Observatory, second series, was issued in February, 1930. It contains the equatorial observations for the period 1908–1926, the photographic equatorial observations for the period 1912–1924, the photoheliographic observations for the period 1917–1927, and an appendix containing the observations made at San Diego, Calif., and at Washington, D. C., during the world longitude operation of 1926.

The material for the reports on the total solar eclipses of 1925, 1926, and 1929, which has been prepared in various divisions, is being arranged for printing.

CONTRIBUTIONS ON ASTRONOMICAL SUBJECTS

In the Astronomical Journal:

1. Washington Observations of the Moon, 1894–1922, by H. R. Morgan. (No. 926.)
2. Corrections to the Elements of the Satellites of Mars, by A. Hall and H. E. Burton. (No. 928.)
3. Elements of the Orbits of the Satellites of Mars, by H. E. Burton. (No. 929.)
4. A New Method of Determining Time, by F. B. Littell and J. E. Willis. (No. 931.)
5. Observations of Asteroids, by J. D. Phenix. (No. 931.)
6. The Aberration Constant from Declinations of Pole Stars, by H. R. Morgan. (No. 933.)
7. Variation of Latitude Observations, by F. B. Littell. (No. 935.)
8. Occultations by the Moon, by A. Hall, H. E. Burton, G. M. Raynsford, and J. D. Phenix. (No. 936.)
9. On the Secular Variation of the Elements of Mercury and Venus, by H. R. Morgan. (No. 936.)
10. Washington Observations of the Moon, 1923–1929, by J. C. Hammond and H. R. Morgan (No. 939).
11. Reduction of Occultations of Stars by the Moon, by J. Robertson. (No. 940.)

In Popular Astronomy:

12. The Photoheliograph of the United States Naval Observatory and Notes on the Recent Sun-Spot Maximum, by G. H. Peters and N. E. Wagman. (January, 1930.)
13. The Naval Observatory Eclipse Expedition to Iloilo, by P. Sollenberger. (October, 1929.)

In Bulletin Horaire:

14. A Method for Evaluating Clock Corrections, by P. Sollenberger. (No. 51.)

Papers before technical societies: American Astronomical Society, August, 1929, Ottawa, Canada, and December, 1929, Boston, Mass.

1. A New Method of Determining Time, by F. B. Littell and J. E. Willis.
2. The Recent Sun-Spot Maximum as Deduced from Mean Monthly Areas at the United States Naval Observatory, by G. H. Peters and N. E. Wagman.
3. A New Method of Driving a Traveling-wire Micrometer, by C. B. Watts.
4. The Crossed Vertical Transit, a New Instrument of Fundamental Astronomy, by J. E. Willis.

Washington Philosophical Society, February and March, 1930:

5. The Transit Instrument and the Synchronous Motor, by C. B. Watts.
6. Recent Experiments with Timekeepers, by J. E. Willis.

Optical Society of America, October, 1929, Ithaca, N. Y.:

7. The Observed Motion of the Perihelion of Mercury, by H. R. Morgan.

Popular lectures: The Solar System, before the Maryland Academy of Sciences; The Naval Observatory, its History and Work, broadcast, Station WRUF; The Solar System, before Benton Engineering Society, University of Florida; The Scientific Work of the Naval Observatory, Junior College, St. Petersburg, Fla.; Astronomy, St. Petersburg, Fla., by G. H. Peters; Naval Observatory Time Service, broadcast, N. B. C., by P. Sollenberger.

General Astronomy: A series of 15 lectures before the Y. W. C. A., Washington, D. C., by J. E. Willis.

Astronomy: Two lectures at Camp Overall, Va., by W. M. Browne.

UPKEEP

The remarks made in previous annual reports regarding the gradual deterioration of buildings, grounds, and roads, through lack of funds applies with equal force to the period covered by this report. Every effort continues to be made to hold in check this deterioration and to make such slight improvements as are possible with our very small force.

With more liberal appropriations, the force could be increased and the appearance of the reservation would soon show the effect.

J. F. Hellweg,
Captain, United States Navy, Superintendent.

Changes in officer personnel

Reported		Detached	
Name	Date	Name	Date
Commander G. W. Kenyon, U. S. N.	July 2, 1929	Lieut. (J. G.) G. U. Quinn, U. S. N.	June 30, 1930
Capt. H. G. S. Wallace, U. S. N.	July 3, 1929	Lieut. Commander L. Wainwright, U. S. N.	July 29, 1929
Lieut. Commander R. Dudley, U. S. N.	Aug. 14, 1929	Capt. (Math.) W. S. Eichelberger, U. S. N.	Sept. 18, 1929
Lieut. Willard Gaines, U. S. N.	Oct. 3, 1929	Lieut J. A. McNamar, U. S. N.	Sept. 27, 1929
Chief Electrician O. E. Dannegger, U. S. N.	Nov. 29, 1929	Lieut. Commander D. B. Downer, U. S. N.	Oct. 8, 1929
Lieut. Robert G. Willis, U. S. N.	Apr. 7, 1930	Chief Electrician E. H. Belknap, U. S. N.	Jan. 15, 1930
Capt. V. K. Coman, U. S. N.	May 12, 1930	Commander G. W. Kenyon U. S. N.	Mar. 4, 1930
Commander Frank Slingluff, jr., U. S. N.	June 2, 1930	Lieut. H. G. Williams, U. S. N.	Apr. 30, 1930
Commander C. H. J. Keppler, U. S. N.	June 9, 1930	Lieut. W. R. Gaines, U. S. N.	Do.
Lieut. Stephen K. Hall, U. S. N.	do	Capt. H. G. S. Wallace, U. S. N.	May 15, 1930
Lieut. Harry Keeler, jr., U. S. N.	do	Lieut. T. T. Craven, U. S. N.	Do.
Lieut. R. C. Welles, U. S. N.	do	Capt. C. S. Freeman, U. S. N.	May 21, 1930
Capt. J. F. Hellweg, U. S. N.	do	Lieut. R. G. Willis, U. S. N.	May 29, 1930
Commander A. G. Stirling, U. S. N.	June 10, 1930	Lieut. Commander E. G. Hanson, U. S. N.	June 10, 1930
Lieut. Marcy M. Dupre, U. S. N.	June 16, 1930	Commander S. F. Heim. U. S. N.	June 14, 1930
Lieut. (M. C.) H. C. Kellers, U. S. N.	do		

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